



# FOCUS

## SCIENCE AND TECHNOLOGY

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**New planets like Earth**

They could host life

**e-cigarettes**

Good or bad for your health?

**Inside swarms**

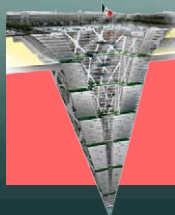
Collective minds explained

# 10 WONDER MATERIALS THAT WILL CHANGE THE WORLD

**PLUS** The materials that shaped the last century

### AGE OF THE EARTHSCRAPER

Why the future of urban living is 50m under the surface



### Q&A

- Does chewing gum really help you concentrate?
- Do laser weapons work?
- Why do women live longer?



### TIME TO GET SMART

On test: watches that bring phone apps to your wrist

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# WELCOME TO FOCUS



LAST SUMMER I spied a 119m-long superyacht in an Italian harbour. If I owned 'Yacht A', I thought, I'd be a very happy man. Accepted wisdom, of course, is that money can't buy happiness. Yet the latest scientific proof shows that in fact it can. And thankfully for most of us, you don't need to spend more of it, as long as you buy the right things. Psychologist Elizabeth Dunn and business

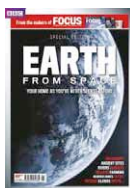
researcher Michael Norton give us the good news on p71.

Scientific discoveries have a habit of making us happier too, at least in the long run. Michael Faraday's 19th Century work on electromagnetic fields started the communications revolution that enabled today's smartphones. But where will the next big revolution come from? One area is materials science. In November 2011, we reported on the exciting prospects for graphene, a form of carbon. In this issue we've picked 10 materials we think will change the world. See p36 to find out if graphene is top of the pile.

Finally, which noises do you find most annoying? Let me know, but first read our article on p50. It explains which sounds are scientifically the most grating – and why. Until next issue,

Graham

Graham Southorn, Editor



**PS** Our new special issue **Earth From Space** goes on sale on 11 June, priced £7.99. To order, visit [buysubscriptions.com/earthfromspace](http://buysubscriptions.com/earthfromspace)

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## APPEARING IN THIS ISSUE...



**Jo Carlowe**

A long-time *Focus* contributor, science writer Jo brings us a fascinating story this month. On p52 she investigates the new imaging techniques that are providing insights into how bees, locusts, starlings and other creatures swarm and communicate.



**Helen Czerski**

Helen is a physicist and a regular presenter on BBC science programme *Dara O Briain's Science Club*. She also has a passion for blueberries. In her regular column on p34, she explains how making blueberry jam went somewhat awry.



**Elizabeth Dunn**

An associate professor in the department of psychology at Canada's University of British Columbia, Elizabeth specialises in happiness. She's the co-author, with Michael Norton, of *Happy Money: The Science Of Smarter Spending*.



**Duncan Graham-Rowe**

A journalist specialising in technology, Duncan's writing has graced *The Guardian*, *The Economist*, *Nature* and many other top publications. In this issue he takes a look at the materials most likely to transform our future.



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### SUBSCRIBER BONUS

On p32, astrobiologist **Paul Davies** looks at how we're closing in on an explanation for the origins of life

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# 10 WONDER MATERIALS





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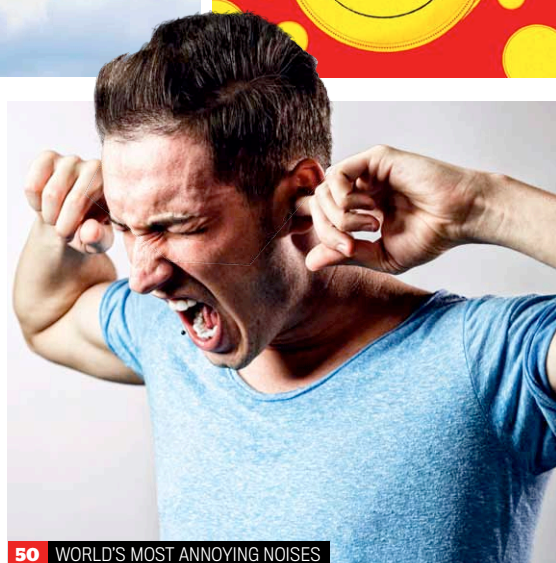
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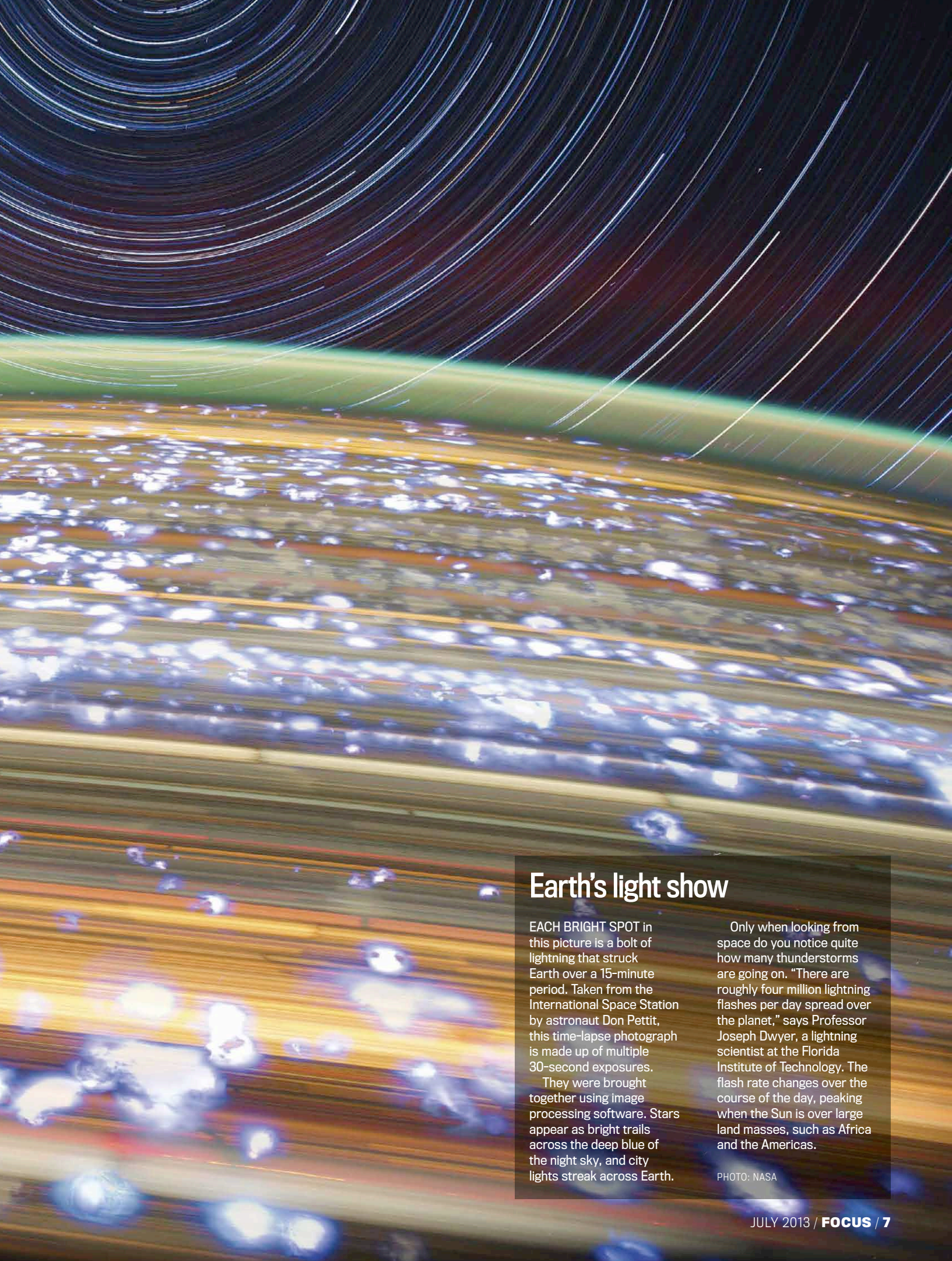


Awe-inspiring images from the world of science

# MegaPixel







## Earth's light show

EACH BRIGHT SPOT in this picture is a bolt of lightning that struck Earth over a 15-minute period. Taken from the International Space Station by astronaut Don Pettit, this time-lapse photograph is made up of multiple 30-second exposures.

They were brought together using image processing software. Stars appear as bright trails across the deep blue of the night sky, and city lights streak across Earth.

Only when looking from space do you notice quite how many thunderstorms are going on. "There are roughly four million lightning flashes per day spread over the planet," says Professor Joseph Dwyer, a lightning scientist at the Florida Institute of Technology. The flash rate changes over the course of the day, peaking when the Sun is over large land masses, such as Africa and the Americas.

PHOTO: NASA









MegaPixel

## Dark matter's nemesis

LOCATED A MILE beneath the Gran Sasso mountain in central Italy, this instrument could finally unmask dark matter – the elusive stuff thought to make up 85 per cent of the Universe's mass. When it starts running later this year, a detector inside this chamber will be hunting for 'Weakly-Interacting Massive Particles' (WIMPs) – physicists' best guess as to what makes up dark matter.

The DarkSide-50 detector will sit at the heart of this metallic sphere and will be filled with liquid argon. The physicists behind it hope a WIMP will collide with an argon atom, giving off light.

But another subatomic particle, the neutron, will produce similar flashes of

light if it passes through the detector. So this outer chamber will be filled with another liquid that is particularly sensitive to neutrons. Boron molecules within it will again flash when struck, the light picked up by 'photomultipliers' in the chamber wall. If there's a flash inside the detector and *not* inside the surrounding boron, it will probably be down to a WIMP.

"If we want to understand how the Universe evolved, or how it'll evolve in the future, we need to know what it's made of," says Dr Chamkaur Ghag, a physicist at University College London working on the experiment.

PHOTO: ENRICO SACCHETTI





+

**MegaPixel**

## Rainbow with no end

THE POT OF gold would be particularly difficult to find at the end of this rainbow – it's almost a full circle. It was spotted at Victoria Falls in southern Africa.

"In fact all rainbows form a complete circle," says Dr Greg Gbur, an optical physicist at the University of North Carolina. "Usually, however, the horizon blocks out half of it so we only see an arc. In this case, though, the Sun was behind the photographer and the water droplets were in the gorge below. That's why the full circular formation can be seen."

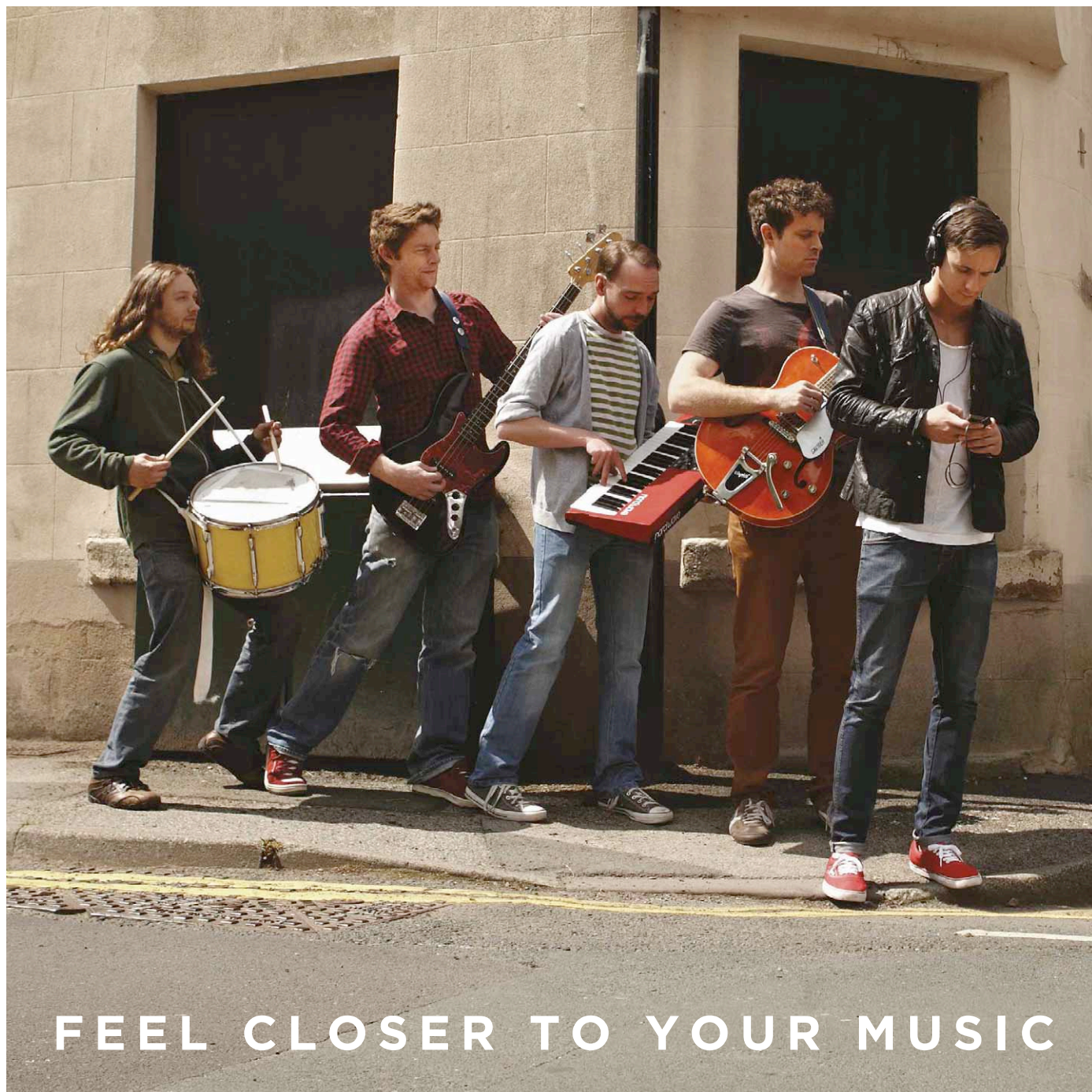
Droplets sprayed up by the waterfall act as a tiny prism, dispersing the sunlight into a spectrum of colours as well as reflecting the light back towards us. It's the combined effect of millions of these droplets that generates this spectacular multicoloured band of light.

PHOTO: REX









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Your opinions on science, technology and our magazine



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Letters may be edited for publication

## MESSAGE OF THE MONTH



The white light: the prospect of eternity in paradise or someone shining a torch in your face?

## Life after death

In his review of Dr Sam Parnia's book *The Lazarus Effect* (p104, May), Dr Tom Stafford fails to say what 'hard evidence' he suggests ought to be provided for the proposition that consciousness persists independently of brain activity, and how such hard evidence might be obtained. If the accounts of those who have experienced after-death resuscitation are in practice the only source of evidence available, then it is unscientific merely to dismiss them as 'anecdotal' and therefore inherently unreliable.

The proper approach would be to accept that such evidence as exists supports Dr Parnia's proposition, until the other explanations to which Dr Stafford refers have been investigated and shown to be responsible for the apparent consistency of the post-death accounts.

But Dr Stafford lets slip his inherent bias by comparing the proposition with tales of fairies living at the bottom of gardens.

There are some propositions for which no amount of data would suffice to persuade those with closed minds.

**Stephen Trahair, Plymouth**

**Tom Stafford replies:** *I am inclined to accept the alternative explanations until they are found to be inadequate. I don't see this as having a closed mind, rather as having strong prior beliefs about the way the mind works. Psychology has taught us a lot about how the mind can trick us into believing strongly in what hasn't happened. Perhaps near-death experiences are an exception, but I've seen nothing compelling to make me think they aren't entirely products of the wonderful human mind.*



**Write in and win!**



The writer of next issue's Message of the Month will win a pair of Wang Buds worth £65.95. The Buds have natural sounding bass and a clear sound, plus a microphone for voice-activated control. See [www.fannywang.com](http://www.fannywang.com) for more information.

## Making a splash

It occurs to me that there may be an alternative to the potential disaster arising from the collapse of the flank of Cumbre Vieja in La Palma (p68, May). The amount of splash and disturbance of water depends to a large extent on the shape of the body entering it.

In the recent ITV programme *Splash*, many of the contestants nearly emptied the pool on entry, whereas Tom Daley entered the water without a splash and there was a minimal wave as a result. If the flank collapse of Cumbre Vieja was of a certain speed and smoothness, it might not make a very large wave.

**Roger D Britton**

**Bill McGuire replies:** *The shape of a sliding mass can indeed influence the scale of the resulting tsunami, as can other factors such as the slide's velocity and how much it breaks up. A worst-case Cumbre Vieja collapse – say 500km<sup>3</sup> entering the Atlantic at 100 metres a second – will, however, generate a colossal wave whatever shape the slide is.*

## Tsunami headache

I got a strange jolt looking at the simulated progress of a tsunami across the Atlantic (May, p71). It looks exactly like the progress of my migraine aura – so much so that I felt a bit queasy looking at the pictures in succession. I don't suppose this will trigger any major advance in the fields of either tsunami prediction or migraine treatment, but I had to share it.

**Jennifer Thorp**

## Say no to real zombies

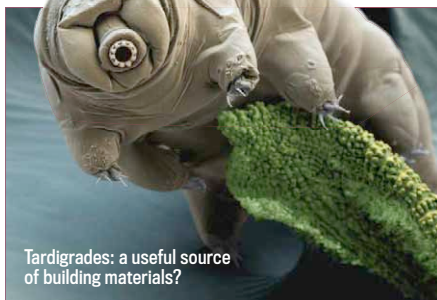
I loved the 'Science of zombies' article in the May issue. In fiction we've had corpses reanimated by evil fogs, curses and natural disasters. Man is capable of great leaps in science. But it's a good thing we are no nearer in the real world to bringing such monsters to life.

**Matthew Wilson, Wolverhampton**

## Strange science

I just read your fascinating magazine, which brought up many thoughts. If tardigrades (p57, May) are so tough, why





Tardigrades: a useful source of building materials?

don't they make houses and cars out of them? Perhaps crush them down first because they look kind of ugly...

I was also rather saddened to read that the Russian meteor was just that – a meteor. I had fantasised that perhaps it might have been a Venusian spacecraft.

Lastly, if you wanted more info about zombies, you only had to ask me because I have them living next door. They make all kinds of loud noises and frankly I don't like the look of them. I see them eating meat a lot: their barbecue is on almost all the time but I know that is just a cover-up. The truth is far, far more sinister.

**Robert Roemer, Melbourne**

*The mind boggles! –Ed*

## Simulated Universe

Mr E Philpott's letter in the May issue regarding the article about the possibility of a simulated Universe seems a little closed-minded for a science and technology reader. He mocks: "The team leaders of the project should find a tall building and throw themselves off. If everything is a sim, they will bounce. If not: pavement pizza". He goes on to cite the money "wasted" on this project and how it could be put to better use.

The article on 'Masters of mind control' regarding how technology has the power to put our actions in someone else's hands is only too real. I would guess it's used more than we know. We share 99 per cent of our DNA with chimps – that 1 per cent is the difference between eating a banana and scratching, and launching the Hubble telescope. It's not a big step to imagine how a civilisation that's even 1 per cent more intelligent than us could have created a simulated Universe.

**Marian Davies**



Are you just a holographic toy for the pleasure of some advanced race?

## Digital vs analogue

In the Q&A section of the May issue, on page 61 your answer to the question 'Are digital clocks more accurate than analogue clocks?' stated: "The sweep of the hands on an analogue clock is continuous," and concluded that analogue clocks are therefore more precise.

But this is usually not true. On most modestly priced analogue dials, the second hand simply jerks forward once every second. These clocks are no more 'accurate' than a digital display with a six-digit hr:min:sec readout.

**Brian Rumary, England**

## Oops!

- On p38 of the June issue we wrongly converted the distance of Sagittarius A\* from Earth as 254 trillion km from Earth. It should have said 245,000 trillion km.

- On p64 of May's issue, the 'Looking south' chart should have had East on the left-hand side instead of the right.

## YOUR COMMENTS ON FACEBOOK

On facebook.com/sciencefocus, we asked: **Would you buy a genetically engineered glowing plant?** Kickstarter page at <http://kck.st/ZGyck>

**Lewis MacKenzie**

Wow, this would be amazing. I'm very tempted to back it!



**Poderosa Pequeña** What happens when I want the lights off?!

**Lewis MacKenzie** Gutted that the seeds are only available in the USA, but I guess it's a regulatory thing.

**Spike Matthews** I'd certainly give it a pop! I wonder if there is a way of dimming or blocking the light, short of covering the plant...

**Zac Taylor** Maybe it would light up when reacting to darkness! Also, I can't imagine it to be as bright as a light bulb or lamp for that matter.

# FOCUS

SCIENCE AND TECHNOLOGY

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## Life in HD

**Break out of the living room with a system that pumps live HDTV, direct from your HDMI source, all over the house - via your existing plug sockets**

**T**oday's hi-tech world is all about convenience and mobility. We carry all-singing, all-dancing smartphones in our pockets; we have cars equipped with sat-nav and ABS to take the pain out of driving; we watch movies and surf the internet from our seats in planes, trains and automobiles. Yet when it comes to watching a movie or sporting event in crisp, clear high definition, we're still chained to the sofa.

That's where the HD Juicebox comes in. This clever multi-room HDTV system from Aclass Technology lets you send HD Video anywhere in your home using just the existing mains cabling. There's no need for expensive, disruptive rewiring, and you'll never need be frustrated by intermittent wi-fi signals again. Instead, you just connect the HD Juicebox transmitter to your HD source (such as a satellite or cable box, Blu-Ray player, games console or set-top box), connect up to four HD Juicebox receivers to HDTV-compatible displays anywhere in the house, then plug them all into the mains. Most users find they can set up the whole system in 10 minutes - no help required.



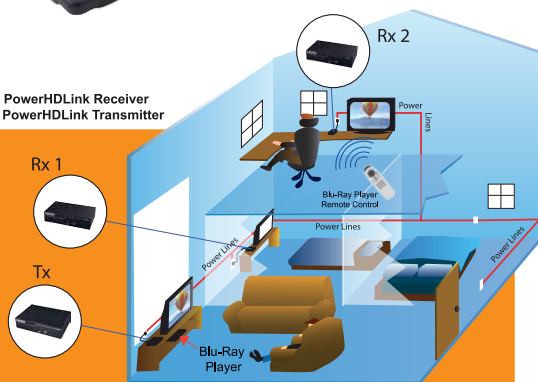
Rx = PowerHDLINK Receiver  
Tx = PowerHDLINK Transmitter

### Want to know the technical details?

The HD Juicebox system uses HomePlug-AV PLC technology to send a high-definition H.264 video signal via existing mains cable, at up to 1920x1080 @60i resolution (other resolutions are also supported). The transmitter and receivers connect to your existing hardware via supplied HDMI cables, and the system supports IR pass-through, which means you can control the source with your existing remote from any room where you've installed a receiver. There's also an Ethernet port so that if you've got a smart TV, its 'smart' functions are also available anywhere in the house.

### Or perhaps you don't want the details...

Perhaps you just want to kick off your shoes and watch the big match or the latest blockbuster in comfort, wherever you are in the house. That's fine - modern living is all about convenience and mobility after all.





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Lab-grown rat organs offer new hope for human transplant patients

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## ELECTRONIC SMOKING

Are e-cigarettes any better for you than tobacco? We ask the experts – and you

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## ALL EYES ON YOU

New security camera inspired by compound eyes of insects

### THE BIG STORY

## Earth-like worlds discovered

Planets similar in size to our own could have the conditions to support life

TWO PLANETS HAVE been discovered that are the most similar in size to Earth ever to be found in their star's habitable zone – the area in which liquid water, and therefore potentially life, could exist. Yet, as intriguing as this new discovery is, we may never know what these planets are really like.

Both worlds orbit the star Kepler-62, which lies 1,200 light-years from Earth. Kepler-62e, the closer



An artist's impression of planet Kepler-62f, one of the most Earth-like worlds discovered

PHOTO: NASA



ANALYSIS

Sara Seager



Professor of Planetary Science and Physics at MIT

THIS IS ONE of Kepler's most significant findings. It is delivering on its promise to take a census of how many Earth-sized planets there are around Sun-like stars. What we want to know is whether every star has a planet about the size of Earth.

Kepler is looking at so-called 'transiting planets', and for that to work they have to pass in the line of sight between the telescope and the star. The probability of that happening is very small. So for Kepler to try and find lots of Earth-sized planets, they decided to look at more than 150,000 stars. To see so many stars, they all had to be very far away. But that means the stars are faint, so we don't have enough information to really learn any more about the nearby planets once they have been discovered.

But a new exoplanet-hunting mission, the Transiting Exoplanet Survey Satellite (TESS), will be launched in 2017. TESS will look around the whole sky, not just at one patch of faraway stars like Kepler. As a result, TESS stars will be much closer to Earth.

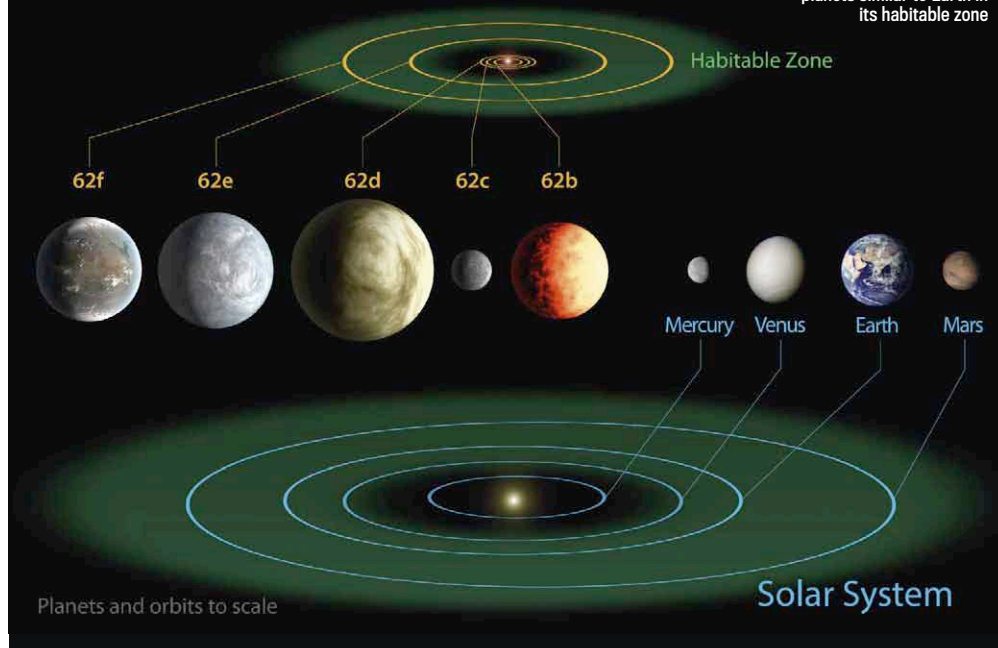
We hope that the stars near the rocky planets TESS discovers will be bright enough to allow follow-up research to reveal the planets' atmospheres. That's really exciting, because the combination of using TESS to find the planets and the forthcoming James Webb Space Telescope to look at their atmospheres could give us our first chance of finding signs of life on another world.

WHAT DO YOU THINK?

Will we soon discover extraterrestrial life? Let us know your thoughts at [facebook.com/sciencefocus](https://www.facebook.com/sciencefocus)

# Kepler-62 System

The alien solar system of the star Kepler-62 has planets similar to Earth in its habitable zone



of the two new exoplanets to the parent star, is 60 per cent larger than Earth, while its smaller sibling 62f is just 40 per cent larger.

"These are two of the most exciting planets we've ever found," says Dr William Borucki, a Kepler scientist working at NASA's Ames Research Center in California and lead author of the study, announcing the discovery in the journal *Science*. The Kepler space telescope, after which the star was named, spotted the planets by looking for the tiny dips in brightness they cause as they pass in front of, or 'transit', the star. A third, slightly larger planet in another star's habitable zone was recently found using the same technique. Kepler-69c is around 70 per cent larger than Earth.

NASA believes Kepler-62e and 62f to be rocky or icy planets. A separate analysis of the results by astronomers in Germany and the US suggests 62f could be entirely covered with water. There is even more uncertainty about the composition of Kepler-69c.

The atmospheres of these planets will be of crucial importance in determining whether

they host life. "If you have carbon dioxide and water, that would be good. If you have oxygen, there might very well be life," says Borucki.

## PEERING INTO DARKNESS

But we're a long way from finding that out – and we may well never know. These planets are too small and too far away to work out whether they have atmospheres. Even the composition of the planets is not much more than an educated guess based on the limited data available, such as their size.

Kepler's first discoveries were large, gaseous planets in close orbit around their parent stars. They were relatively easy to detect, because of their size and the fact they pass in front of their stars so frequently. But now, technical refinements enable planet hunters to spot smaller bodies.

"We're moving from simply finding lots of planets to the point where we're finding these planets in the habitable zone," says Borucki. "It's a wonderful thing. We'll be finding even smaller ones in the coming year or two."

KELLY OAKES

## TIMELINE

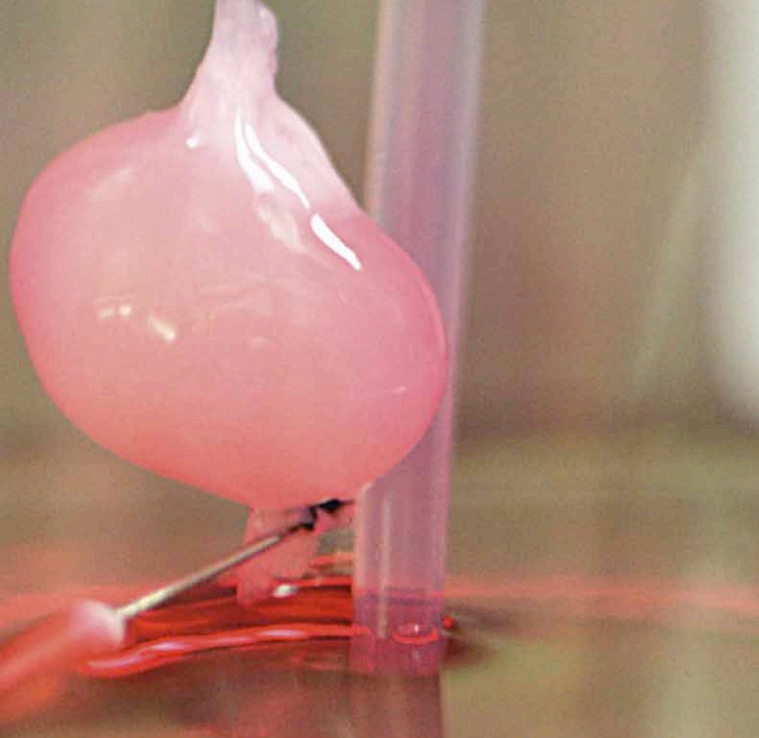
A history of exoplanet discovery

1992	2010	2011	2011	2013	2013
The first two exoplanets are discovered in orbit around pulsar PSR B1257+12, which lies 980 light-years away in the constellation of Virgo. A third planet has since been discovered in this system.	Gliese-581g, touted as the first habitable exoplanet, is found by the Lick-Carnegie Exoplanet Survey. But another team says it is unable to confirm its existence.	The Kepler mission finds its first rocky planet, Kepler-10b, in January. It is just 1.4 times the size of Earth but orbits its star 20 times closer than Mercury orbits the Sun.	The discovery of Kepler-22b is announced in December. It is the first planet found by Kepler within its star's habitable zone, but is over twice the size of Earth.	In January, astronomers estimate that, based on Kepler data, one in six stars hosts a planet up to 1.25 times Earth's size, giving a total of 17 billion Earth-sized planets in our Galaxy.	The discovery of Kepler-62e and 62f, as well as Kepler-69c, is announced in April. They are the first Earth-sized planets to be discovered within the habitable zones of their parent stars.





This lab-grown kidney consisting of human and rat cells could pave the way for artificial organ transplants



## Medicine

# Lab-grown kidney is successfully transplanted

**R**ATS HAVE BEEN fitted with kidneys grown in a lab using human cells. It's the first time that artificial kidneys have been successfully transplanted into a live animal and marks a significant step on the road towards artificial kidney transplants in humans.

While simple artificial organs such as windpipes have already been transplanted into human recipients, this is the most complex organ to be grown artificially and transplanted. Dr Harald Ott and his team at Massachusetts General Hospital in Boston stripped the kidneys of dead rats using a detergent to leave a collagen 'scaffold'. They then seeded these structures with living cells which developed into functional kidneys.

Two cell types were used: human vein cells lined the blood vessels and kidney cells from newborn rats populated the other areas. The artificial kidneys worked, but only produced around one-third as much urine as normal

kidneys and got rid of creatine – a waste product – 36 times more slowly. So more development work is still needed.

"Getting the cells to the right spot was the biggest challenge," says Ott. His team coaxed the cells into position by sending them along tubes attached to each kidney's artery, vein and ureter – the duct through which urine exits.

There are currently 7,000 people waiting for a donor kidney in the UK and 100,000 in the USA. Ott hopes 'hybrid' kidneys, genetically tailored to the recipient, will confine such statistics to the history books.

Other researchers are also working to develop artificial kidneys: Prof Anthony Ayala at Wake Forest Institute for Regenerative Medicine in the US, for example, is working on a 3D kidney printer. "It makes me happy that there are lots of us working on different ways to reach the same goal," says Ott, who is now testing his technique using human kidneys.

**ZOE CORMIER**

## 1 MINUTE EXPERT KALQ keyboard

### What's that?

A new keyboard layout designed to speed up two-thumb typing on mobile phones and tablets.

### What does it look like?

The keyboard is split into two sections – one for each thumb. All the vowels are on the right-hand side, while the left thumb is assigned more keys (and vice versa for left-handers). The name comes from the bottom row of letters on the right.

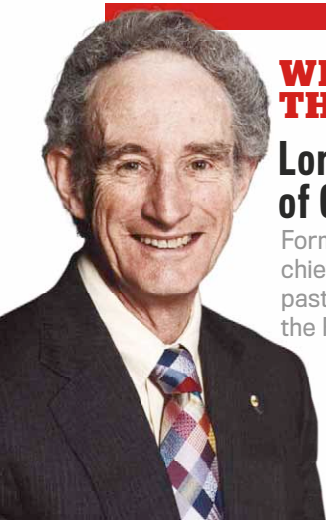
### How does it speed up typing?

The position of the letters has been optimised using a computer algorithm developed by researchers led by Dr Antti Oulasvirta at Germany's Max Planck Institute for Informatics. The algorithm had models of thumb movement built into it. It calculated the keyboard layout that would minimise the distance travelled by each thumb, while also allowing the user to alternate between thumbs as much as possible.

### Does it work?

It seems to. After a bit of training, KALQ users managed an impressive 37 words per minute – most people can't manage more than 20 words per minute on a standard QWERTY touchscreen keyboard.

Anyone wanting to try out the KALQ keyboard for themselves can download a free app for Android smartphones.



## WHO'S IN THE NEWS?

### Lord May of Oxford

Former government chief scientist and past president of the Royal Society

#### What did he say?

He gave a damning response to a study in which Chinese scientists mixed the H5N1 flu virus, which is not easily transmitted by people, with a strain of the H1N1 virus, which is very infectious in humans. "They claim they are doing this to help develop vaccines," Lord May told *The Independent*. "In fact the real reason is that they are

driven by blind ambition with no common sense whatsoever."

#### How did they reply?

Prof Hualan Chen at China's Harbin Veterinary Research Institute says they were trying to emulate what happens when an animal is infected with two strains of a virus, which can cause genes to be 'swapped' between strains. They created

127 viral hybrids, five of which were able to pass by airborne transmission between guinea pigs.

#### Isn't this kind of research banned anyway?

No. US and Dutch researchers who created airborne versions of H5N1 in 2011 imposed a voluntary moratorium on their research, but they have since lifted their self-imposed ban.





# PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd



## Good photos, rain or shine

IF YOUR PHOTOS can sometimes look somewhat amateurish, then Google has the solution – a camera system that knows exactly where you are and tunes its settings according to the local weather conditions.

Google's camera will detect its location using GPS and download weather data from the internet to determine the local ambient light level. It will then adjust parameters such as white balance, saturation, sharpness and contrast to

suit the conditions. The system could be built into a smartphone or tablet.

While built-in light meters are already commonplace on digital cameras, the search giant suggests that this technology would provide an extra degree of accuracy. So whether you're hiking up a rain-swept mountain or sunbathing in the tropics, you'll no longer have to fiddle about with those awkward manual controls.

**Patent application number:**  
US 20130076926

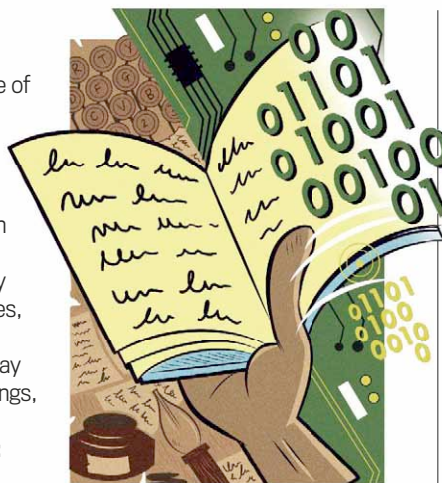
## eBooks go flexible

SONY HAS PLANS for an eBook reader that could convert even the most ardent devotee of paper books into a digital bookworm.

The thin, flexible device can be folded along its centre like a standard book. The flexibility of the gadget's material also increases towards the edges, giving the outer parts a similar feel to paper. To increase the book-like experience, when a user bends one of the corners, a sensor picks up the movement, allowing them to flick through the pages.

Sony's reader will make use of the latest advances in flexible electronics. The screen could be a pliable 'electrophoretic' display, in which particles of pigment are arranged using an electric field. The patent also describes how the technology might be used in mobile phones, personal audio players and laptops, with the flexible display being used to flick through songs, web pages or pictures.

**Patent application number:**  
US 20130070431



## The tethered glider

A US INVENTOR has come up with a novel method of generating electricity – a glider that harnesses the strong winds high in the sky. Dimitri Chernyshov's unmanned glider would be connected to a generator on the ground by a long tether. When winds pick up, the glider is launched, reaching heights of over 350m. As the glider is taken by the wind and the tether is drawn out, the kinetic energy is transformed into electricity.

**Patent application number:**  
US 8421257



If you're going to steal a bike beware the evil eyes



**THEY DID WHAT?!**

## Staring eyes placed over bike racks

### What did they do?

Large pictures of piercing eyes with a short anti-theft message beneath were placed over three

bike racks on the Newcastle University campus by professors from the University's Centre for Behaviour and Evolution.

### What happened?

In the year after the eyes were put up, bike thefts in the racks watched by the eyes dropped by 62 per cent compared with the previous year. Elsewhere on the campus, thefts rose by

63 per cent. This follows earlier research by the same team that showed people put nearly three times more money in a tea room honesty box, and are more likely to clear away trays in a café, if eyes are watching them.

### Will we see this elsewhere?

Yes. British Transport Police are trialling eye pictures on the London-Southend train line.



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Can *A. sediba* shed new light on mankind's very earliest origins?



## Anthropology

# New evidence that *A. sediba* was an early relative

**D**ETAILED STUDIES OF the two-million-year-old remains of a hominin discovered in 2008 add more weight to the idea it was an early ancestor of ours. *Australopithecus sediba* had an intriguing mix of both ape- and human-like characteristics – implying it was a link between the two.

Six studies published in the journal *Science* show that while *A. sediba*'s arms were ape-like, its hands and wrists were like ours. It also had an ape-like torso and a human-like pelvis. This cocktail of traits points to *A. sediba* being a close ancestor of the *Homo* genus – the group of animals that included the likes of *Homo ergaster*, *Homo heidelbergensis* and ultimately us, *Homo sapiens*.

However, although the indications are increasingly strong, anthropologists are still undecided as to whether *A. sediba* really was a direct ancestor of *Homo* species.

“There were many different species all coexisting, with all these different anatomies in weird combinations – it’s hard to tell which evolved into our own lineage,” says Assistant Professor Jeremy DeSilva at Boston University, who was involved with the research.

The new research shows *A. sediba* would have taken short, quick steps with the outer edge of its foot hitting the ground first, instead of the heel as in humans. But, says DeSilva: “I think bipedalism evolved early in this entire group, before large brains, and these creatures did not amble about poorly. If you walk around clumsily, you are leopard food.”

The job of untangling our history from our ancestors’ remains never ceases to thrill, DeSilva says. “By leaving us their bones, they have given us an incredible gift – a way to understand why we all are the way we are.”

**ZOE CORMIER**



## CLICK HERE

New sites to explore

### FIRST MEN ON THE MOON

[firstmenonthemoon.com](http://firstmenonthemoon.com)

Whether you remember the Moon landings or not, this site uses video footage, communications audio and more to put you far closer to Eagle’s historic descent than ever before. Look out for the little details, like Neil Armstrong’s heart rate reading, that make this a truly immersive experience.

### THE GENOGRAPHIC PROJECT

[genographic.nationalgeographic.com](http://genographic.nationalgeographic.com)

The Genographic Project has been answering questions about the spread of the human race since 2005, and you can learn more about it on this new website. Joining in the experiment will mean shelling out \$199 (£130) for a DNA-testing kit, but if that’s not an option the site still has plenty of information on the science behind the project for you to explore.



National Geographic’s Genographic Project aims to track humanity’s spread across the globe

### TIME AND NAVIGATION

[timeandnavigation.si.edu](http://timeandnavigation.si.edu)

If you’ve ever wondered how navigation takes place in space, or how ships were directed without so much as an accurate clock, this online version of a new exhibition at the Smithsonian Museum in the USA is the site for you.

### HIEROGLYPH

[hieroglyph.asu.edu](http://hieroglyph.asu.edu)

Hieroglyph is a project with a lofty aim – to encourage science fiction writers to pen stories which inspire scientists to invent transformational technology. The project’s attractive website is packed with ideas that should get the creative juices of even the most jaded scientist flowing.





## GRAPHIC SCIENCE

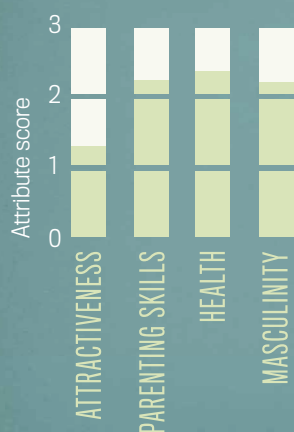
Seeing research differently

IF YOU'RE THINKING of shaving off a few days' growth of facial hair, think again – if you're a man, at least. A study carried out by scientists in Australia discovered that women find 10 days of stubble more attractive than the clean shaven look.

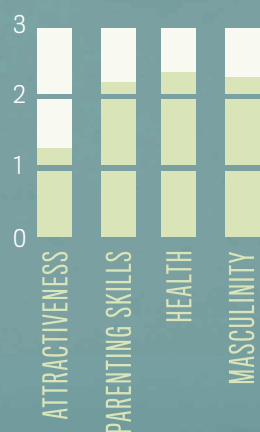
Researchers at the University of New South Wales, Sydney showed 350 women photos of men with differing amounts of facial hair, asking them to rate them from 0–5 in four categories: attractiveness, parenting skills, health and masculinity. Men with 'heavy

stubble' (10 days' growth) scored most highly for attractiveness. In their report, published in the journal *Evolution And Human Behaviour*, the researchers write: "A threshold of density and distribution may be required for beards to function as an attractive signal."

### CLEAN SHAVEN



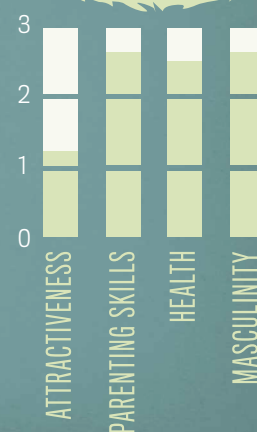
### LIGHT STUBBLE



### HEAVY STUBBLE



### FULL BEARD



## NEWS IN BRIEF

### Rare fish is a throwback

• The genome of the coelacanth, a fish that looks very similar to 300-million-year-old fossilised fish, has been sequenced. The team behind the analysis calculate that the genes of the very rare fish, which lives off the coasts of Africa and Indonesia, evolved much more slowly than those of other animals. This would account for its primitive appearance.



### Pain on the brain

• Your doctor will soon be able to measure how much physical pain you're in with a brain scan. Neuroscientists at the University of Colorado, Boulder found that activity increased in certain brain regions, including the anterior cingulate cortex, when volunteers were subjected to painful heat. Emotionally 'painful' experiences did not evoke the same response.

### Dark matter spotted?

• Scientists may have finally glimpsed dark matter. One of two detectors in a former iron mine spotted signs of 'weakly interacting massive particles', one potential form of dark matter. But the researchers at the CDMS-II detector in Minnesota say there's still a possibility they could have got the same results by chance.



## HOT TOPIC

One million people in the UK are expected to be puffing on e-cigarettes this year

# Are e-cigarettes good or bad for you?

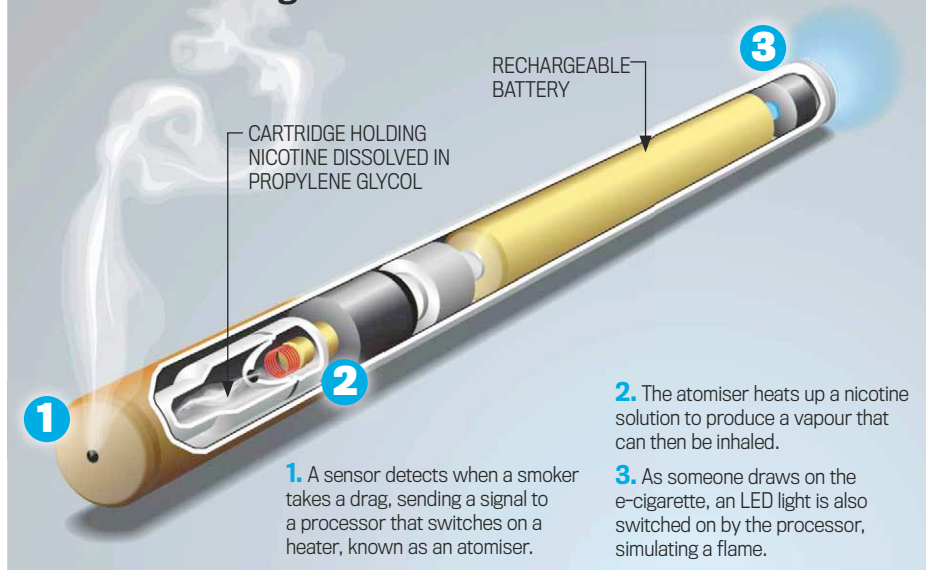
**F**IVE YEARS AGO, hardly anyone had heard of them. Today, at least 700,000 people in the UK are estimated to use electronic cigarettes, and that's expected to rise to one million this year. But just how safe are they?

Many smokers see e-cigarettes as a way to quit. They look like a traditional cigarette and provide a nicotine hit from the vapour. At the same time, there's no

burning tobacco, eliminating toxins such as arsenic and hydrogen cyanide.

"Nicotine itself isn't an especially hazardous drug," says Professor John Britton at Nottingham University, who is Director of the UK Centre for Tobacco Control Studies. "In terms of risk, it's probably on a par with caffeine. It's the other constituents of tobacco smoke that cause all the harm."

### Inside the e-cigarette



### WHAT DO YOU THINK?

Let us know your opinions at [twitter.com/sciencefocus](https://twitter.com/sciencefocus) using the hashtag #hottopic, as well as [facebook.com/sciencefocus](https://facebook.com/sciencefocus)



**Barbara Bass:** I tried all the other nicotine products such as patches and gum. Nothing worked.

Three months of e-cigs and I'm a happy non-smoker for more than a year!



**Kieron Donlon:** No good ever comes from inhaling anything other than air. The choice you have is

between known risk and unknown risk. I recommend abstinence.



**Ricky Cann:** Until studies show otherwise, I'm all for e-cigs as a life-changing alternative for people

trapped by years of smoking tobacco.



**Dawn Costen:** I'm not sure, but I HOPE they are not bad as I have been using them since the end of

November last year and have smoked no 'real' cigarettes since!

So far, there have not been any long-term studies of the health effects of e-cigarettes: most research has concentrated on identifying what smokers are inhaling along with the nicotine. In 2009, the US Food and Drug Administration (FDA) analysed the cartridges of two leading brands of e-cigarettes and found traces of diethylene glycol – a toxic liquid – in one cartridge, and traces of carcinogenic chemicals called 'tobacco-specific nitrosamines' (TSNAs) in half of them. A review of the FDA report commissioned by e-cigarette maker NJOY points out, however, that TSNAs have been found in other FDA-approved nicotine products.

Whether e-cigarettes help people to stop smoking is the subject of two trials whose results are due later this year. One involves 300 smokers in Italy, the other 657 in New Zealand. The British Medical Association says there is not yet enough evidence to show that e-cigarettes are a safe, effective way to quit smoking, and advises doctors to recommend other nicotine products, such as patches.

"E-cigarettes aren't licensed as medicines in the UK, so there's very little control over what's in them," says Prof Britton. "We do need better regulation of the devices but, in the meantime, people shouldn't be prevented from buying them."

**JAMES LLOYD**





A false-colour image of an enormous hurricane raging on Saturn; how it is fuelled is a mystery

## Astronomy

### Hurricane spotted on Saturn...

WITH AN EYE that's 2,000km (1,250 miles) wide surrounded by fast-moving, swirling clouds, this hurricane on Saturn was photographed by NASA's Cassini spacecraft. Researchers say the wind in the wall of the eye is travelling four times faster than hurricane winds on Earth. But apart from its size and wind speed, it's strikingly similar to its terrestrial counterparts.

"This vortex looks so much like a hurricane on Earth," says Prof Andrew Ingersoll, a Cassini imaging team member at California Institute of Technology. "But there it is on Saturn, on a much larger scale – and it is somehow getting by on the small amounts of water vapour in Saturn's hydrogen atmosphere."

Hurricanes on Earth feed off oceans. There is no such body of water close to this Saturnian hurricane, so finding out how it uses vapour will provide insights into what happens on Earth.

**ANDY RIDGWAY**

## Meteorology

### ...and 'dark lightning' studied on Earth

WHEN THUNDERSTORMS RAGE, invisible flashes of high-energy radiation sometimes accompany regular lightning. The flashes, dubbed 'dark lightning', are gamma rays. Although they carry many times more energy than conventional bolts, the energy shoots off in all directions and doesn't go far. The burning question is: what would happen to passengers in a plane that just happened to be in the wrong place at the wrong time? Would they be exposed to potentially lethal levels of radiation?

This was the question that Dr Joseph Dwyer and his team at the Florida Institute of Technology set out to answer. Their new model predicts how dark lightning is produced in storms and matches previous observations by satellites.

And the verdict? Passing through such a burst in an aircraft could expose you to radiation equivalent to a full-body medical CT scan, says Dwyer. So, not fatal and the risk is also low. Pilots try to avoid flying through thunderstorms, and dark lightning only occurs once for every 1,000 bolts of standard lightning.

**JAMES LLOYD**



ifa-berlin.com

# Stay in touch

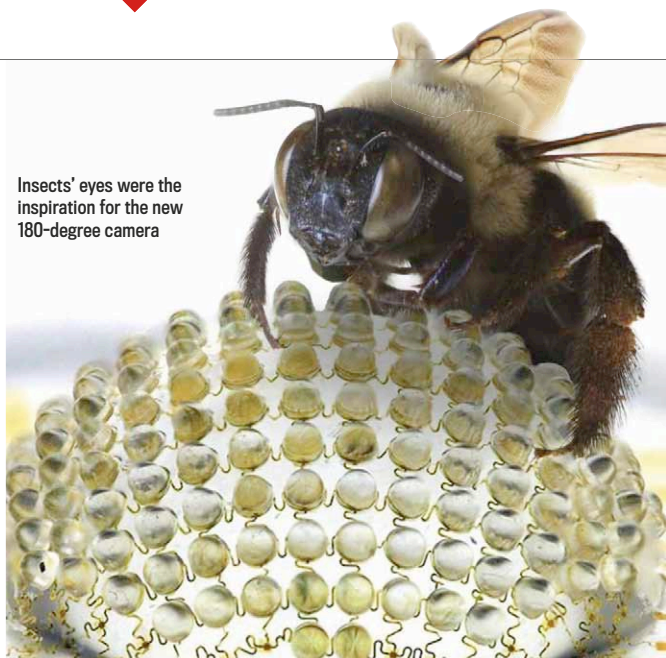


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Insects' eyes were the inspiration for the new 180-degree camera



## Technology

### The many eyes have it

A NEW MANY-LENSED camera inspired by the compound eyes of insects could be watching over us in future. With 180 lenses, each pointing in a slightly different direction, it would make the ideal security camera. The idea would be that a surveillance system could combine all the images into one, just like an insect's brain does.

Developed by Professor John Rogers at the University of Illinois at Urbana-Champaign, the camera has a grid of tiny light-sensitive diodes made out of silicon. Each diode is connected by flexible S-shaped wires and has a tiny lens fitted over it. The whole thing is then formed into a dome.

This set-up has a few advantages over standard cameras with one lens: it gives clear vision across the entire 180° field of view, as well as being sensitive to movement.

## Asteroid strike

### Rock clue to Tunguska mystery

THREE ROCKS FOUND in a river bed may have finally solved the mystery of exactly what exploded over Siberia over 100 years ago.

In June 1908, a huge explosion near the Podkamennaya Tunguska River knocked down 80 million trees over a 2,150km<sup>2</sup> (830 square miles) area. The generally accepted theory is that the blast was the result of a comet or meteorite exploding in the Earth's atmosphere, but no direct evidence has ever been found.

Now Dr Andrei Zlobin, a geologist at the Russian Academy of Sciences, says he has found three rocks in the Khushmo River with clear signs of melting, as well as impressions on the surface of meteorites caused by friction as the rock falls through the atmosphere. Chemical analysis of the rocks must now be carried out to confirm Zlobin's hypothesis.



The Tunguska explosion was 1,000 times more powerful than the Hiroshima bomb



## WHAT THE PAPERS SAY

Henry Gee on the latest from leading journals

### DOGS AND THEIR OWNERS REALLY ARE ALIKE

EVERYONE KNOWS the saying about dogs and their owners looking alike. But does it have any basis in fact? Curiously, the answer is yes – at least at the microbial level.

Dogs and their owners exchange their bacterial residents, just as cohabiting people do. Because dogs tend to pick up different bacteria from those acquired by people, dogs and their owners share a different range of bacteria from those simply exchanged between humans.

This is one result of a study by Dr Rob Knight of the University of Colorado at Boulder and colleagues, published in the journal *eLife*. It sounds obvious, but the effect has never been measured and could have implications for human health.

The researchers specifically mention the so-called 'hygiene hypothesis', which suggests that early exposure to a wide range of microbes in the environment – including those living on pets – helps to train the immune system not to overreact to things we come into contact with later. It's this overreaction that is thought to lead to disorders such as eczema, asthma and hay fever. But the hygiene hypothesis is just that – a hypothesis – and is hard to test. This research could provide a way into the question, by allowing researchers to identify those bacteria that dog-owners get

from their dogs and work out any links with other maladies. For instance, are people who grow up around dogs more or less likely to be asthmatic?

The researchers surveyed 159 people and 36 dogs living in 60 families, concentrating on bacteria living on the skin and fur. They found human skin to be dominated by three kinds of bacteria – propionibacteria (which cause body odour), staphylococci and streptococci – while dogs harbour a much wider range. This more diverse fauna inhabits our

skin when we're in close contact with dogs.

The researchers list all the pets owned by the families, including cats, guinea pigs and even a tarantula.

But apart from the human-dog interaction, they didn't compare microbial communities in any depth. The human-dog link is arguably the most interesting as dogs have been close companions of humans far longer than any other animal.

Incidentally, my own menagerie includes two dogs, four cats, a rabbit, chickens, two snakes, tropical fish and an axolotl. If Dr Knight and colleagues are interested in the wider effects of pet ownership, they know who to call.



HENRY GEE is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*



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## INSIDE SCIENCE

# ROBERT MATTHEWS

**D**OES CLIMATE SCIENCE have anything in it straightforward? If there is, I've yet to come across it. Take that most basic of climatic facts: it's warmer in the summer than the winter (well, in theory anyway). The explanation is obvious: the Earth is closer to the Sun at this time of the year. Er, well no, it isn't: in early July the Earth is actually furthest from the Sun.

Sure, our distance from the Sun affects the warmth we get, but it's less important than the effect of the tilt of the Earth's axis. And during summer, our hemisphere is tipped towards the Sun, so its rays strike the ground more vertically, leading to more intense heating per square metre.

If you didn't know this, don't beat yourself up. Some years ago, Harvard University researchers found that barely 1 in 10 newly graduated students could explain why it's warmer in summer.

Climate scientists know all this, of course, but even they regularly get caught out by the tricky nature of their subject. Take the current controversy over what's happening to the sea-ice surrounding Antarctica. If our planet is warming up, then obviously the amount of sea-ice will shrink. Yet since 1985, the amount of sea-ice around the Great White Continent has actually *increased* by around 2 per cent per decade. Not very much, to be sure – but enough to make climate scientists the butt of jokes from global warming sceptics.

Undeterred, climatologists are working hard to understand what's going on. Using a computer simulation of the climate – the weapon of choice in this branch of science – a team from the Royal Netherlands Meteorological Institute thinks it's resolved the paradox of warmer seas producing more ice. Here's how it works: the warm sea-water melts the overlying ice, creating a layer of cold melt water underneath. Being less salty, this layer is also less dense, and so floats on top of the warmer sea, spreading outward and freezing over during the winter months, thus boosting the amount of sea-ice.

If you think that's a bit convoluted, don't worry: there are other explanations. How about this from the British Antarctic Survey: global warming over Antarctica has changed its wind patterns, leading to ice being blown off the coastline – exposing more seawater to the chilling winds, and thus boosting the amount of sea-ice.



**“Climate scientists are wrestling with problems of hideous complexity – we need to cut them some slack”**

Of course, both explanations could be partly true, or indeed neither. But what is undoubtedly the case is that this combination of paradoxical findings plus convoluted explanations leaves the impression of climate science being an unreliable source of insight. The scientists can hardly be blamed for that. They are wrestling with problems of hideous complexity, and doing it in the full glare of publicity. The rest of us need to cut them some slack, as the last thing we need is to bounce them into premature conclusions that prove to be wrong.

Nowhere is this more important than over the current debate over shale gas. Even some environmentalists have argued that while it's still a fossil fuel – and thus a source of global warming carbon dioxide (CO<sub>2</sub>) – it makes sense to switch to shale gas from coal as it releases much less CO<sub>2</sub> per unit of energy. But, in the whole 'cleaner fuel' debate, there's another paradox awaiting the unwary. It's true that shale gas releases less CO<sub>2</sub> than coal, but it also doesn't produce the sulphur and other 'aerosols' released by coal – and these are known to bounce sunlight back into space, offsetting some of the warming effect of burning coal. And it's unclear just how much better shale gas is than coal when that's taken into account.

But it's crucial that we get the right answer, and quickly. Governments are now deciding policy on shale gas, and if they rush to judgement using 'obvious' scientific arguments, we could find ourselves in big trouble. ■

**ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham**





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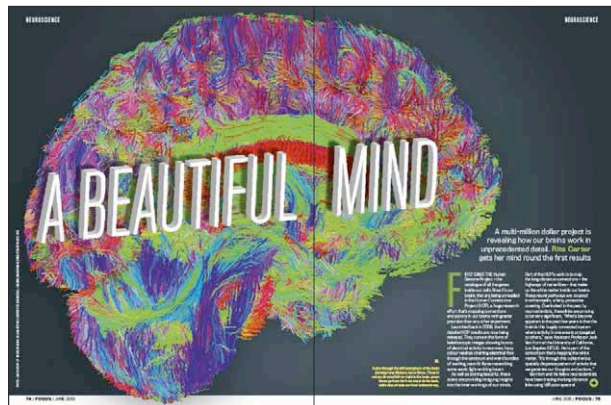
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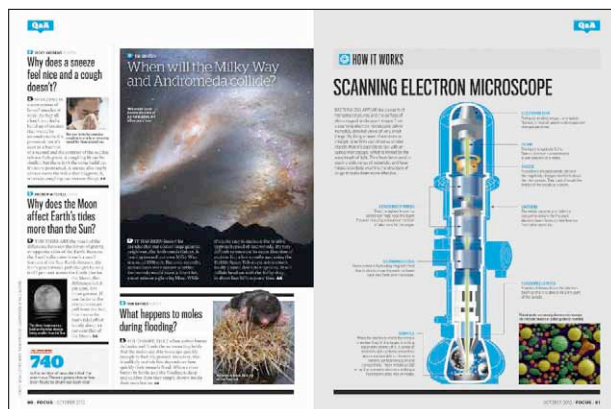
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## HIDDEN TREASURES

# HELEN CZERSKI

**T**HE BLUEBERRY JAM was pink. Bright fuchsia pink. It was a huge disappointment. Three years ago, I was living in Rhode Island in the USA, sorting out the last bits and pieces before moving back to the UK. Most things were done, but there was one last project to do before I left. I had always loved blueberries – they were slightly exotic, delicious, and bizarrely blue. In most places they come in frustratingly small quantities, but in Rhode Island they grow in abundance. I wanted to convert some of the summer blueberry bounty into blue jam to take back to the UK. So I spent one of my last mornings there picking and sorting blueberries.

The most important and exciting thing about blueberry jam is surely that it is blue. I thought so, anyway. But nature had other ideas. The pan of bubbling jam was many things, but blue was not one of them. Pink? Why pink?

Six months later, I was asked by a friend to help with a historical conundrum. He was making a TV programme about witches, and he said that there were records of 'wise women' boiling verbena petals in water and putting the resulting liquid on people's skin as a way of telling whether they were bewitched. He wondered whether they were measuring something systematically, even if it wasn't what they intended. I did a bit of research and found that maybe they were.

Purple verbena flowers, along with red cabbage, blood oranges and lots of other red and purple plants contain chemical compounds called anthocyanins. These anthocyanins are pigments, and they give the plants their bright colours. There are a few different versions, so the colour varies a bit, but they all have a similar molecular structure. That's not all, though – the colour also depends on pH (a measure of acidity). If you make the environment slightly more acidic or more alkaline, the molecules change shape slightly and their colour changes. They are 'indicators' – nature's version of litmus paper.

You can have lots of fun in the kitchen with this. You need to boil the plant to get the pigment out, so boil a bit of red cabbage in water, and then save the water (which is now purple). Mix some with vinegar, and it goes red. A solution of laundry powder (a strong alkali) makes it go yellow or green. You can generate a whole rainbow of outcomes just from what's in your kitchen. I know because I did. I love this discovery because these anthocyanins are everywhere, and accessible to anyone. No chemistry set required!

So maybe these wise women were testing for pH, not bewitchment.

**"The most important thing about blueberry jam is surely that it is blue. I thought so, anyway. But nature had other ideas"**



Not a Heston Blumenthal concoction, this is what Helen really cooked up

Your skin pH can vary naturally, and putting the verbena concoction on skin produces different colours for different people. I could make cabbage water go from purple to blue when I was sweaty after a long run, but it didn't change colour when I hadn't been exercising. It seems to me to be a reasonable hypothesis.

So much for history. And then I remembered the blueberries and the jam. Blueberries are blue because they contain anthocyanins. Jam has only four ingredients: fruit, sugar, water and lemon juice. The lemon juice helps the natural pectin from the fruit do its job of making the jam set. It does that because... it's acid. My blueberry jam was pink because the boiled blueberries were acting as a saucepan-sized litmus test. The excitement

of working that out almost made up for the disappointment of never having made blue jam. Almost. But the discovery that there's a whole rainbow of colour to be had from just one fruit is worth the sacrifice. ■

**DR HELEN CZERSKI** is a physicist, oceanographer and BBC science presenter whose shows include *Operation Iceberg* and *Orbit*



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# 10

## MATERIALS THAT WILL CHANGE THE WORLD

From flexible gadgets to cloaking devices and living concrete, the future is set to be transformed

WORDS: Duncan Graham-Rowe

A QUIET REVOLUTION is currently under way in labs around the world. Scientists are finding ways to manipulate matter at increasingly small scales, as well as drawing inspiration from biological materials. This revolution is giving us substances with properties that were once confined to the pages of science fiction books.

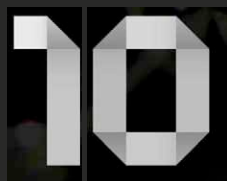
But these materials are more than just scientific curiosities – they are genuinely useful, to the point that as applications start to emerge they will radically change our world.

Here at *Focus* we've combed research papers and patent applications to bring you the top 10 most influential materials coming your way.





Ferrofluids can be teased into unusual shapes with a magnetic field, a property that might one day be used to treat cancer



## FERROFLUIDS

THE SHAPE-SHIFTING FLUID THAT COULD TRANSFORM CANCER TREATMENT

IF YOU WERE to try to build a real life Terminator T-1000, the shape-shifting robot assassin in *Terminator 2*, you could do a lot worse than start with a ferrofluid. Just like T-1000, ferrofluids are a liquid metal that can change shape. Their abilities are down to the fact that they contain microscopic particles of magnetite or hematite, or some other compound containing iron, dispersed in a liquid. As such, this liquid is magnetic, which allows it to be coaxed into position.

Ferrofluids have quietly crept into everyday use. Held in place by magnets, they form a liquid seal around spinning hard drives in computers, preventing debris drifting in and causing your holiday snaps to be wiped. They're also used in speakers. But they have much greater potential. NASA has been experimenting with them in spacecraft attitude control systems and Canadian researchers say they could be the next generation of telescope mirrors, able to shift their shape to compensate for atmospheric distortion.

One of the biggest areas of potential is medicine. At Virginia Tech in the US, researchers are exploring the use of a ferrofluid containing iron oxide nanoparticles to treat cancer. The fluid would be directed into a tumour by magnets before an oscillating magnetic field is applied. This would cause the ferrofluid to vibrate, generating heat and killing the cancer cells. "The ideal treatment increases the temperature of the tumour cells for about 30 minutes while maintaining the healthy tissue temperature," says Professor Ishwar Puri who is leading the research. While the technique works, clinical trials are some way off. ➔

### APPLICATIONS

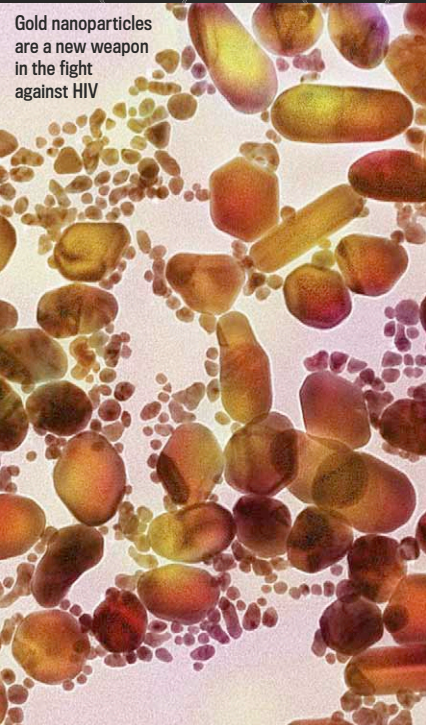
- Spacecraft control
- Telescope mirrors
- Cancer treatment





# GOLD NANOPARTICLES

A NEW GOLD STANDARD IN HIV TESTS



Gold nanoparticles are a new weapon in the fight against HIV

MEDIEVAL STAINED GLASS artisans were the first nanotechnologists. They may have been completely oblivious to the physics of what they were doing, but their techniques led to tiny particles of gold becoming trapped in glass that emit a ruby red colour. Now, instead of illuminating biblical scenes, gold nanoparticles are to be used in new tests for deadly conditions, such as HIV, that are more sensitive and easier to read than current tests.

At the scale of the very small, the realm of nanotechnology, materials take on new properties. While a solid lump of gold is, well, gold, tiny particles can produce different colours depending on how they clump together. Researchers at Imperial College London have put this to good use. Their HIV testing solution is packed with ions (electrically

charged atoms) of gold. When blood serum is dropped into it, what happens next is determined by whether it contains the HIV virus. If it does, put simply, the level of hydrogen peroxide in the solution drops and irregular nanoscopic clumps of gold are produced, producing blue light. If no HIV is present, then the solution becomes awash with hydrogen peroxide and spherical gold nanoparticles are generated, which produce red light.

So sensitive is the test it can detect attograms, or billionths of a billionth of a gram, of HIV protein in a millilitre of human serum, even better than the, ahem, current gold standard. And crucially, the colour change is so distinct it can be read by the naked eye – current tests require expensive machines to read the all-important change of hue.

Professor Molly Stevens, who led the research at Imperial, says

a practical test isn't far off: "So far we have demonstrated a proof of concept including testing with human HIV positive samples. The technology now needs optimising to make it more portable and user-friendly. That could take less than five years."

What's more, the test can be altered to detect other diseases such as malaria, prostate cancer and tuberculosis.

## APPLICATIONS

- HIV detection
- Prostate cancer detection
- Tuberculosis and malaria detection



# POLYURETHANE BLOCK COPOLYMER

THE TRANSPARENT MATERIAL THAT STOPS BULLETS IN THEIR TRACKS

IMAGINE A MATERIAL that could stop a speeding bullet travelling at 350 metres per second even when it's little more than 3cm thick, enveloping it with no marks or cracks in its surface. If this material makes up the windscreen of your presidential limousine or the armoured troop vehicle you're travelling in, it could just have saved your life.

The material in question goes by the uninspiring name of polyurethane block copolymer. Its ability to seal up at the point of entry is explained, according to Professor Ned Thomas, an engineer at Rice University in Houston, by the fact that it melts as the bullet makes contact at high speeds. This seems to play a part in arresting the projectile, dissipating the energy. It then reseals, plugging the gap left behind. This is a sequence of events Thomas has only recently been able to fathom by studying the material under an electron microscope.

As well as bullet-proof glass, polyurethane could end up in body armour and even on the outside of spacecraft and satellites, absorbing space junk and other projectiles that might otherwise cause

serious damage. Using a piece of steel with similar dimensions would be less effective at stopping fast-moving projectiles as well as being seven times heavier, says Thomas.

## APPLICATIONS

- Jet engine turbine blade protection
- Satellite protection
- Bulletproof windscreens
- Bulletproof armour



Professor Ned Thomas holds a chunk of polyurethane block copolymer that has successfully stopped three bullets



A microwave invisibility cloak, developed by scientists at Duke University in the US, uses copper rings and wires patterned onto fiberglass sheets

# 7 METAMATERIAL INVISIBILITY CLOAKS

## BENDING LIGHT WAVES TO MAKE THINGS DISAPPEAR

METAMATERIALS GET THEIR incredible properties not from their many component parts, but from the intricate ways these parts are fashioned. It's this complicated architecture that gives them properties that aren't found in nature – metamaterials are strange by definition. "Usually materials scientists are presented with a substance, determine its properties and only then come up with a use for it. But metamaterials work in the opposite direction," says materials scientist Professor Costas Soukoulis at Iowa State University.

A key target for materials scientists is the invisibility cloak, which would come with a myriad of military and consumer uses. To become a cloak, the metamaterial needs to contain nanostructures that give it a negative refractive index, allowing light to be bent unnaturally so it entirely passes around an object. If done successfully this could render the object, be it an aircraft or even a person, invisible.

As remarkable as this might sound it is not science fiction. Scientists have already demonstrated the

principle. So far, however, they have had more success in bending microwaves than visible light. And this wave bending has been achieved with large, desk-mounted constructions that can only make objects of a given dimension disappear.

However, in November 2012, researchers at Yonsei University in Seoul, South Korea, and Duke University in the US announced they have developed a metamaterial cloak that's able to adapt to changes in the object's shape. That said, the changes could be no more than 10mm and it still only works with microwave-frequency light. So aircraft will not be disappearing from our skies just yet.



### APPLICATIONS

- Cloaking device
- Optical computing
- Spacecraft infrared heat or cosmic radiation shield
- Medical imaging





# PROGRAMMABLE MATTER

A MATERIAL THAT CAN SPONTANEOUSLY FORM INTO A COFFEE CUP... OR A ROBOT

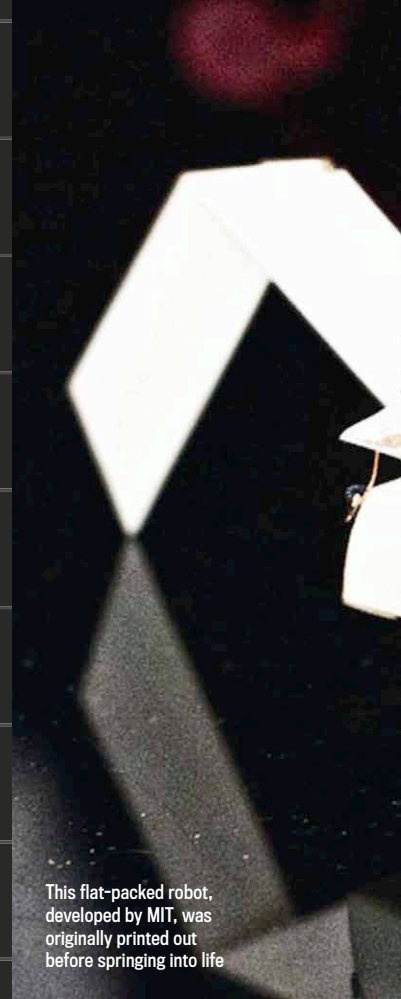
THE THINGS THAT currently make up our world are a pre-defined shape, only changing as they weather or decay. But what if our materials were 'alive', able to change their form on demand? A screwdriver could turn into a spanner, a fleet of robots could spring into shape in the field of battle after being transported in 2D... and a flat-packed wardrobe could assemble in front of your eyes.

It sounds like the stuff of fantasy, but 'programmable matter' could bring such shape-shifting products into our lives. Programmable matter already exists in the labs at Massachusetts Institute of Technology (MIT). Here shape-memory alloys - metals that can change their form when exposed to heat or a magnetic field - are combined with extremely thin electronic circuit boards. These boards provide heat in just the right place to fold the alloys into a pre-defined shape. "This opens the possibility of a world where we are able to program not just computation, but also matter," says Professor Daniela Rus at MIT, who is leading the research.

Rus and her team have programmed their flat sheets to fold into origami classics such as planes or boats, as well as more complex forms including a functional insectoid robot capable of fetching and carrying. "Instead of carrying a toolbox with lots of specific items in them like screwdrivers and wrenches, you could carry around a small pallet of these sheets that you would use to create something for a particular function," says Rus.

## APPLICATIONS

- Self-assembling robots
- Universal toolkits



This flat-packed robot, developed by MIT, was originally printed out before springing into life



# SELF-HEALING CONCRETE

AN 'INFECTED' BUILDING MATERIAL WITH AN EXTENDED LIFETIME

MIXING BACTERIAL SPORES with concrete sounds like a recipe for structural failure, but it could actually extend the life span of bridges, buildings and roads by up to 40 per cent. And given that US President Obama is currently seeking \$50 billion to repair America's highways, bridges and airports, the benefits of longer-lasting building materials is clear.

At Delft University of Technology in the Netherlands, microbiologist Dr Henk Jonkers has developed a microbe-filled concrete

that has a longer life thanks to its innate ability to repair itself, microcracks spontaneously disappearing. While cracks of less than 0.4mm tend not to reduce overall strength, they can allow the ingress of water, which can both weaken the concrete when it freezes and carry damaging substances inside.

"We add a 'healing agent' to the concrete mixture, composed of bacterial spores

- dormant bacteria - and a suitable feed surrounded by a coating," says Jonkers. When a crack occurs, it breaks open the spores and the feed. "Incoming water activates the spores, converting them into active bacteria, which turn the feed into limestone." The species of bacteria used, *Bacillus cohnii* and *Bacillus pasteurii*, are not harmful and are adapted to the highly alkaline conditions within the concrete. They convert the calcium lactate feed into tough calcium carbonate. Outdoor tests still need to be carried out but if successful, self-healing concrete could be in production in just four years.

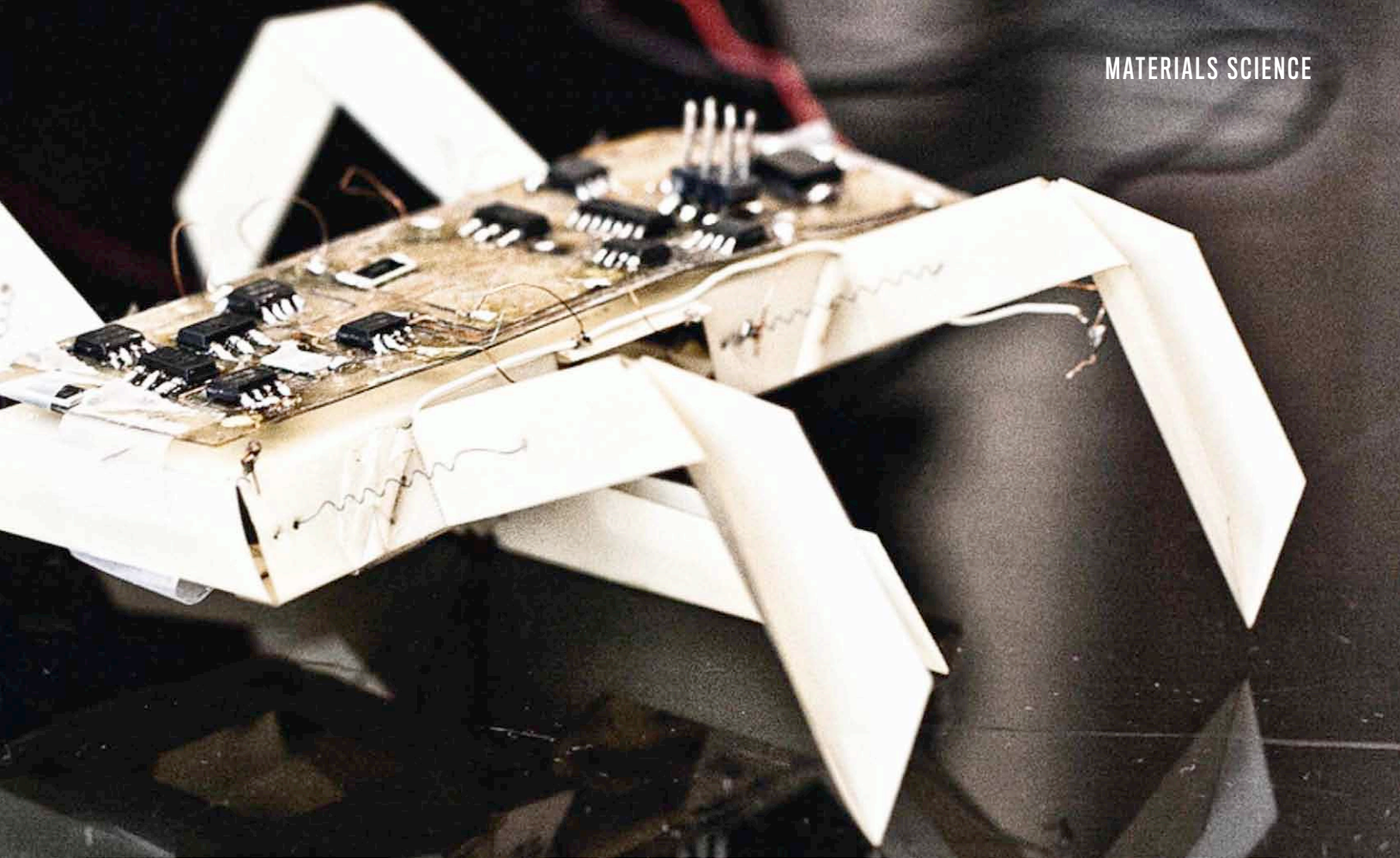
## APPLICATIONS

- Tunnels
- Viaducts
- Roads
- Marine structures

Bacteria-infused concrete can heal over cracks







# 4 DNA HYDROGELS

A SHAPE-SHIFTING MEMORY GOO THAT WILL BE USED IN MEDICINE AND ELECTRONICS

ADDING WATER TO something usually makes it runnier. But when water is added to one new material, it spontaneously takes on a new shape. Welcome to the weird world of DNA-filled hydrogels.

Hydrogels are highly absorbent, sponge-like networks of polymers that readily absorb up to 100 times their mass in water. They are already found in some contact lenses and in the conducting sticky pads on EEG heart monitors. But at Cornell University in the US, Professor Dan Luo – a specialist in putting DNA to unusual uses – has been adding synthetic strands of genetic material to these gels.

In a demonstration, Luo and his team created hydrogels in moulds shaped like the letters DNA. When they poured the gels out, they formed amorphous blobs. But when water was added, the gel formed into the letters again. The DNA becomes entangled inside

the gel, behaving a little like rubber bands glued together.

DNA strands will lock onto other strands with complementary coding. By designing genetic material that links in specific ways, the team hopes to tune the gel's properties.

The hydrogel could be used in medicine – a drug-infused gel would fit a wound exactly. It could even be used in electronics as a water-activated switch. In one test at Cornell, a gel infused with metal particles was placed between two electrical contacts, conducting electricity. When water was added, the gel shortened and the contact was lost.



## APPLICATIONS

- Scaffolds for tissue engineering
- Drug-filled wound plugs
- Water-activated switches



DNA is able to spell itself when incorporated in a hydrogel that reacts with water – the material could be used in medicine to form a perfect plug for wounds



# IONIC LIQUIDS

A MORE ENVIRONMENTALLY FRIENDLY WORKHORSE OF THE CHEMICAL WORLD

TAKE SOME TABLE salt, heat it to 800°C and you'll see something curious. Instead of blackening and giving off noxious fumes, it will just melt and turn to liquid without any chemical decomposition, much like an ice cube turning to water. In this form, the salt is remarkably good at dissolving stuff.

Now imagine a similar substance, but one that melts at room temperature and you'll have a good idea of what an ionic liquid, or fluid salt, is like. Unlike the vast majority of the multibillion-dollar industrial solvents that keep the modern world ticking over, ionic liquids don't form vapours. This may not sound like the most exciting of properties but it means they're far less dangerous and polluting than many current chemical staples. It makes them useful as charge-carrying liquids in devices like batteries and low-cost solar cells because their stability means they will last longer.

Besides being capable of dissolving almost anything, ranging from the dangerous bacterium MRSA to poisonous mercury found in natural gas, ionic liquids are also likely to lead to the development of a raft of new chemical products because of the unusual ways they react with other materials.

One of the most promising uses of ionic liquids is for storing hydrogen as fuel for eco-friendly cars. Currently, hydrogen is stored as a compressed gas in high-pressure tanks. But this requires a large tank to



Professors Ken Seddon (left) and Jim Swindall from Queen's University Ionic Liquid Laboratory with a bottle of their ionic liquid

hold enough hydrogen for a long journey. An ionic liquid could store a lot of hydrogen in a small space, releasing it when required by the onboard fuel cell.

The possibilities seem endless. "Wherever a conventional liquid can be used, it can in principle be replaced by an ionic liquid designed to be better," says Professor Ken Seddon, co-director of the Queen's University Ionic Liquid Laboratory in Dublin. It's little wonder that this year, ionic liquids topped the Great British Innovation Vote run by the Science Museum.

## APPLICATIONS

- Green cleaning solvent
- Fuel cells for cars
- Solar cells



# GRAPHENE

STRONGER, BENDIER, MORE CONDUCTIVE, AND COMING TO A PHONE NEAR YOU SOON

ONE MATERIAL HAS become synonymous with the word 'miracle': graphene. A new potential use of this two-dimensional sheet of pure carbon is announced almost weekly. Ten thousand research papers were published last year on graphene.

According to Professor Andre Geim at the University of Manchester, who won the Nobel Prize for Physics in 2010 for co-discovering it, it is the strongest material ever measured, the stiffest material we know and has the largest surface area-to-weight ratio, with one gramme capable of covering several football pitches. Graphene's ultra-thin structure also gives it interesting electrical properties – it's highly conductive for starters.

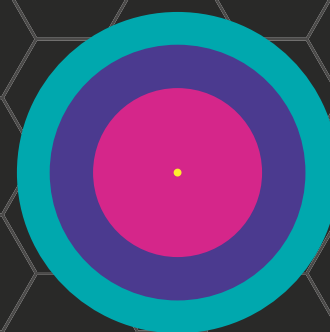
Unknown 10 years ago, research on graphene was awarded 1 billion Euros earlier this year, so great is its promise. Products containing graphene are starting to creep onto the market – a tennis racket made by Australian manufacturer Head being among these trailblazers. A glance at the list of the top 10 graphene patent applicants, which includes Samsung, SanDisk 3D (which makes 3D circuits) and Xerox, provides an indication of where it will have the biggest impact on our lives.

Until very recently graphene may well have taken the top spot of our Wonder Materials line-up – it's certainly worthy. But there's a new kid on the materials block that just pipped it to the post.

## APPLICATIONS

- Flexible computer displays
- Faster microprocessors
- Stronger, lighter composites (tennis rackets and bikes)
- More efficient solar cells
- Sensors
- Medical imaging
- Flexible batteries

## SOURCE OF GRAPHENE PATENT APPLICATIONS\*



China - 2,204  
US - 1,754  
South Korea - 1,160  
UK - 54

\* Applications by the end of 2012 according to CambridgeIP



## THE MATERIALS THAT HAVE SHAPED OUR PAST



**PROF MARK MIODOWNIK**  
ON THE

### 20TH CENTURY'S MOST SIGNIFICANT MATERIALS

#### Silicon

In the 1950s, by understanding the electronic behaviour of matter, scientists invented a solid material able to perform computation: the silicon chip. This paved the way for the computer, the internet, and the mobile phone, all of which have a piece of silicon at their heart. It is silicon then, that connects us all and allows us to Skype our family from afar, or phone our friends while walking down the road.

#### Float glass

These thin glass sheets made by floating molten glass on a bed of molten metal – a technique invented in the 1960s – have been used by architects to create the look of modern cities. It has changed architecture. Float glass has also changed the life we lead inside these buildings – allowing walls of light to flood the interior.

#### Nickel superalloys

These metals democratised aviation, making it available to rich and poor. They contain nickel, aluminium and titanium along with more than 10 other elements and were made into tough crystals in the 1980s. These superalloys allow the jet engine turbines of aeroplanes to operate reliably at the high temperatures required to make engines efficient and safe, thus making cheap travel possible.

**MARK MIODOWNIK** is a materials scientist at UCL, BBC presenter and the author of *Stuff Matters: The Strange Stories Of The Marvellous Materials That Shape Our Man-Made World* (Penguin, £18.99)

# SILICENE

MOVE OVER GRAPHENE, THIS IS THE MATERIAL THAT WILL REVOLUTIONISE GADGETS

SINCE ITS DISCOVERY in 2004, graphene has been basking in the materials science limelight. But a substance with a similar-sounding name, silicene, will ultimately take the glory by revolutionising the electronics industry.

"Silicene is the silicon counterpart of graphene," explains Associate Professor Yukiko Yamada-Takamura at the Japan Advanced Institute of Science and Technology who is a world leader in silicene research. Where graphene is a single layer of carbon atoms, silicene is a single layer of silicon.

In many ways silicene behaves like graphene – it is highly electrically conductive for instance, allowing electrons to flow through it almost unhindered. But it has a crucial advantage over its carbon counterpart – being silicon-based it is highly compatible with existing silicon circuitry. That means less research time to bring new silicene-based products to market and lower manufacturing costs. It will also have the same benefits as graphene – fast computational speed and little energy lost as heat. So in the long run it will be silicene supercharging your smartphone, not graphene.

Silicene also beats graphene in its structural flexibility. Whereas graphene can only take one form, with its atoms in a specific horizontal lattice, silicene

is different. "Silicene can be flexible at the scale of the atom, so the atoms can be displaced out of the plane," says Yamada-Takamura. These subtle shifts in silicene's atomic structure mean its electrical properties can be changed, increasing the number of potential uses.

Silicene's moment of glory is some way off – it was only created for the first time last year by researchers in Germany. That's a far cry from the raft of graphene-led patents that have already been registered around the world. But ultimately, it is silicene that will have the biggest impact on our lives. ■

#### APPLICATIONS

- Electronic chips
- Digital storage
- Catalysts for mopping up pollution

**DUNCAN GRAHAM-ROWE** is a technology journalist with a degree in electronic engineering

The two-dimensional honeycomb structure of silicene could soon be powering advanced gadgets

#### What do you think?

Are there any wonder materials we've missed from our top 10 list? Let us know at [reply@sciencefocus.com](mailto:reply@sciencefocus.com)



Join the conversation on Twitter.

Tweet @sciencefocus using the hashtag #focusmaterials



# OUR FUTURE



City planners and architects tight for space are increasingly looking beneath their feet for the solution. Are we destined to live subterranean lives?

**Words:** Daniel Cressey **Illustration:** The White Balance  
**Additional reporting:** Andy Ridgway, Alice Udale-Smith



# UNDERGROUND



**T**OWARDS THE SOUTH of Nevşehir province in central Turkey once lay the ancient city of Derinkuyu. At its peak, 20,000 people lived there. From its beginnings in the 8th century BC, it became a thriving community with wine and oil presses, stables and chapels as well as livestock. All of this would be unremarkable, except for one thing – the entire city was built underground. In places, it extends 60m below the surface.

Even more surprisingly, Derinkuyu was not the only underground city in this part of Turkey. It is linked to another, Kaymakli, by a tunnel that's 8km long. In fact, there were over 30 underground cities in what was once the Cappadocia region alone. These underground communities were occupied by several civilisations, and became a place of refuge for early Christians in the years before Christianity became an accepted religion.

Back in the 21st Century, a growing band of visionary engineers and architects are once more looking underground. But this time their motivation is not to escape religious persecution – their goal is to escape overcrowding.





## UNDERGROUND CITIES

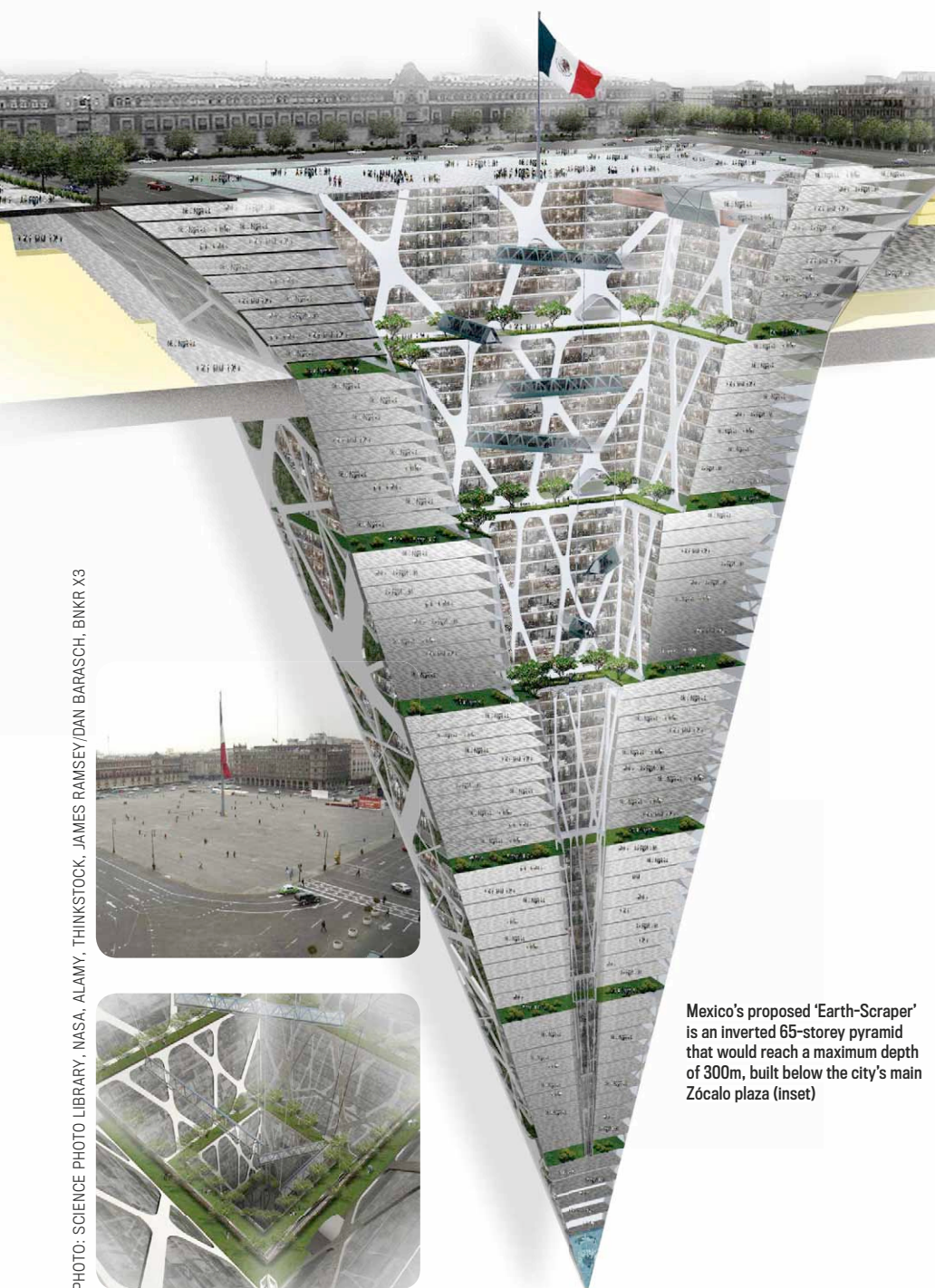
→ In 2018, building work will start on a £7.4bn underground city beneath Amsterdam's famous canals, complete with shopping, leisure and parking facilities. Singapore, Toronto and Frankfurt are also planning major underground developments.

### SUBSURFACE LIVING

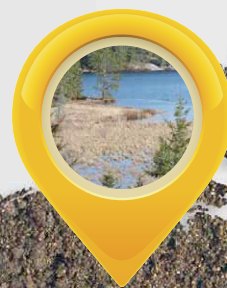
Rather than just shopping underground, Mexicans could soon be living there. A 65-storey 'Earth-Scraper' proposed for

Mexico City would drop some 300m (984ft) below the city's main square. The upturned pyramid, created by Bunker Arquitectura, would have a 10-storey glass core, sending light into the 10 storeys of homes, 10 of shops and 35 of offices below.

Even if you don't have pillaging Romans to worry about, living beneath the Earth's surface has distinct advantages.



Mexico's proposed 'Earth-Scraper' is an inverted 65-storey pyramid that would reach a maximum depth of 300m, built below the city's main Zócalo plaza (inset)



**Central Canada**  
At the Canadian Shield - North America's ancient geological core - the solid, stable craton rock exposed at ground level also extends deep below the surface.

## PRIME SITES FOR UNDERGROUND CITIES

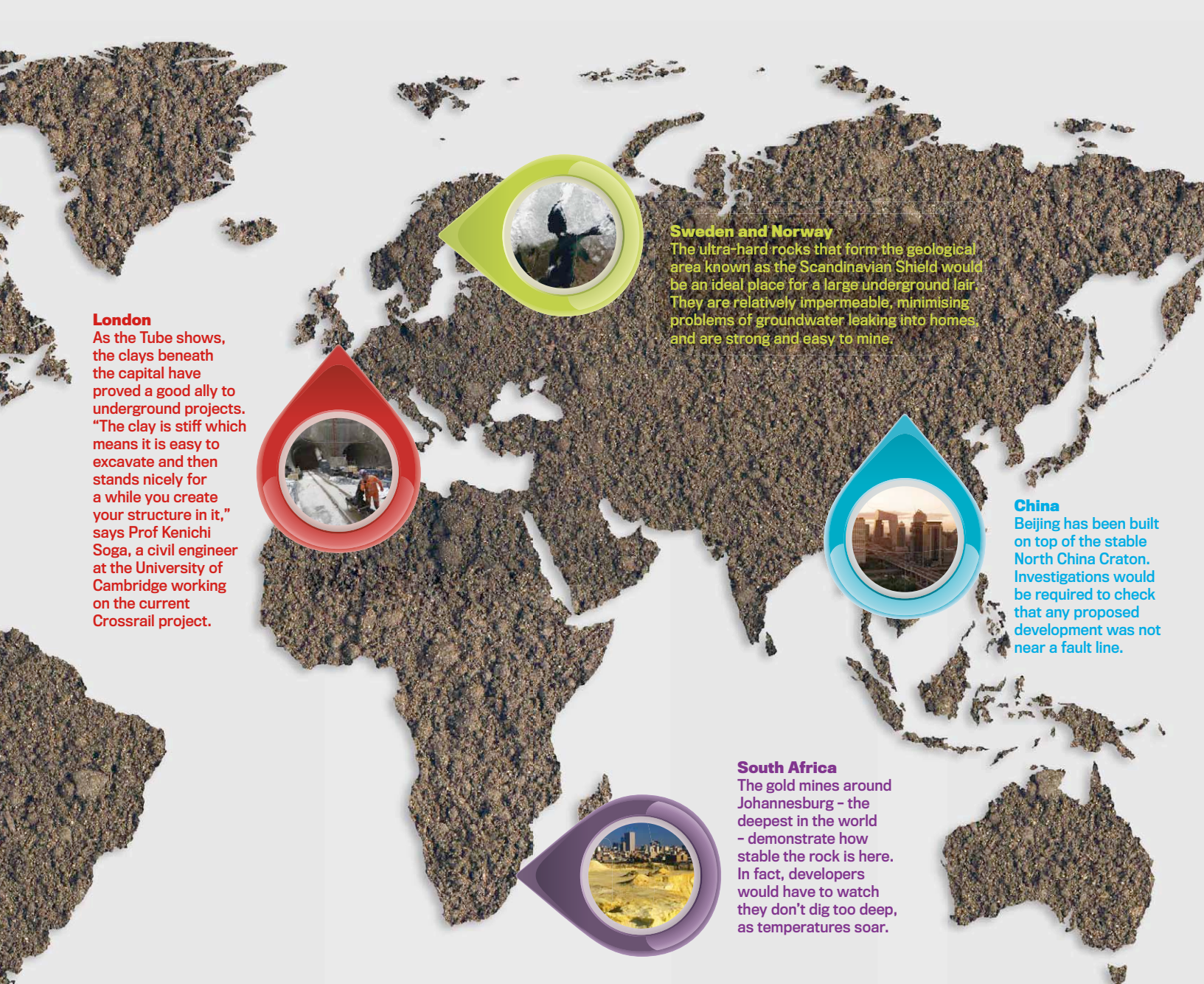
Locations where rocks are suitable for subsurface development on a grand scale

"If you look at phenomena such as natural disasters, where would you rather be: on the 50th floor of a high-rise, or underground?" says Prof Samuel Ariaratnam, an engineer at Arizona State University who was one of the authors of a US National Academy of Sciences report on the future of underground urban development. And if conditions on the

**"Where would you rather be: on the 50th floor of a high-rise, or underground?"**

Prof Samuel Ariaratnam on the benefits of living underground in the event of natural disasters





### London

As the Tube shows, the clays beneath the capital have proved a good ally to underground projects. "The clay is stiff which means it is easy to excavate and then stands nicely for a while you create your structure in it," says Prof Kenichi Soga, a civil engineer at the University of Cambridge working on the current Crossrail project.

### Sweden and Norway

The ultra-hard rocks that form the geological area known as the Scandinavian Shield would be an ideal place for a large underground fair. They are relatively impermeable, minimising problems of groundwater leaking into homes, and are strong and easy to mine.

### China

Beijing has been built on top of the stable North China Craton. Investigations would be required to check that any proposed development was not near a fault line.

### South Africa

The gold mines around Johannesburg - the deepest in the world - demonstrate how stable the rock is here. In fact, developers would have to watch they don't dig too deep, as temperatures soar.

surface take a turn for the worse due to climate change, then a shield of metres of earth and rock could well become more desirable than a balcony with a city view.

Ariaratnam admits that the immediate cost of building down is higher than building up: "I don't think you'll see reverse skyscrapers in my lifetime," he says. But in the longer term, safe from the exposure to the elements, the advantages start to emerge and below ground is, he suggests, the way to go in many places. "Look at hot, humid climates, or very cold climates. Who wants to be outside?"

## PARK LIFE

Even parks could one day be found deep down. Proposals in New York envisage a 'Lowline' park in a huge space left disused since the demise of a tram system in 1948. Its name is a nod to the city's successful High Line park, which





# DEEP DWELLINGS

Some people have already adopted a subterranean lifestyle

1m below the surface



## KANDOVAN, IRAN

Caves dug into volcanic ash formations are said to have been inhabited for the past 6,000 years. In a typical four-storey Kandovan house, the ground or first floor is used as an animal shelter, the next two floors are living areas and the top floor is used for storage. The homes are known as *karan*, which roughly translates as 'beehives'.

1m below the surface



## SUBTERRA CASTLE, KANSAS, USA

This underground bunker was built by the US military in the 1960s to house its Atlas E nuclear missiles. Now part of the former silo has been transformed into a family home, complete with its own 'spiritual' room and an outdoor hot tub. Accessed by tunnel and housing a replica of the control room, the constant reminder of its former life might not be to everyone's taste.

1.8m below the surface



## COOBER PEDY, AUSTRALIA

The cooler temperature of these 'dugouts' burrowed into the side of hills provides a welcome escape from the scorching heat above, where the temperature often tops 40°C. As a result, this opal mining town now hosts one of the biggest underground communities in the world, with 1,500 residents living below the surface. There's even an underground church.

2m below the surface



## CAVE HOUSE, MISSOURI, USA

Inside a 1,400m<sup>2</sup> (15,000ft<sup>2</sup>) cave in Missouri is this modern home, which has three bedrooms as well as three groundwater springs. Geothermal heating keeps the rooms comfortable. The home's walls are simply the sandstone walls of the cave but they do shed sand, so there are artificial ceilings to stop debris falling down.

155m below the surface



## SALA SILVERMINE HOTEL, SWEDEN

Although it's not actually a house, the £380-a-night hotel suite is the deepest inhabited place on Earth. Situated in a single chamber at the bottom of an old silver mine, the claustrophobic may want to give this one a miss. Guests access the room via a mine lift shaft and are left alone overnight with only an intercom connection with the ground above.

## "The vast majority of people have no problem taking the London Underground"

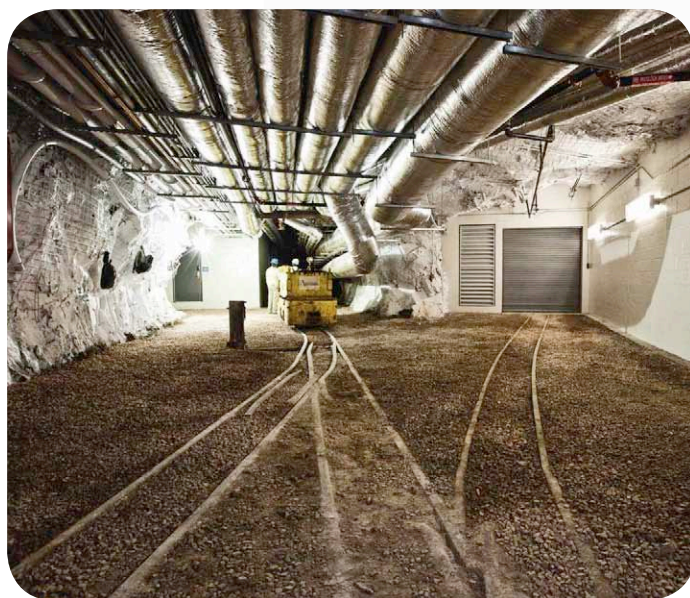
Dr Raymond Sterling on the minimal psychological impact of living below the Earth's surface

→ was built on an abandoned elevated railway in west Manhattan.

Mirrors and fibre optics would bring natural daylight to this cavernous void. 'Sunbeamers' – reflective tubes – would play a key part in this, channelling huge shafts of natural sunlight from above. A full-scale prototype has trialled some of these light-capturing innovations, which should allow grass, bushes and even trees to flourish far from the surface.

Existing underground developments have shown how phenomena we associate with the surface can be brought below ground. At Sanford Underground Research Facility – a laboratory complex in South Dakota that has levels from 90m down to nearly 2,500m – architects worked with in-house psychologists to try and make the environment as pleasant as possible: Screens show blue skies and ventilation systems create noticeable air flows to mimic the breezes above ground.

These designs are intended to prevent any psychological problems. But Dr Raymond Sterling, professor



Ventilation at Sanford Underground Research Facility mimics natural breezes



# TUNNEL VISIONS

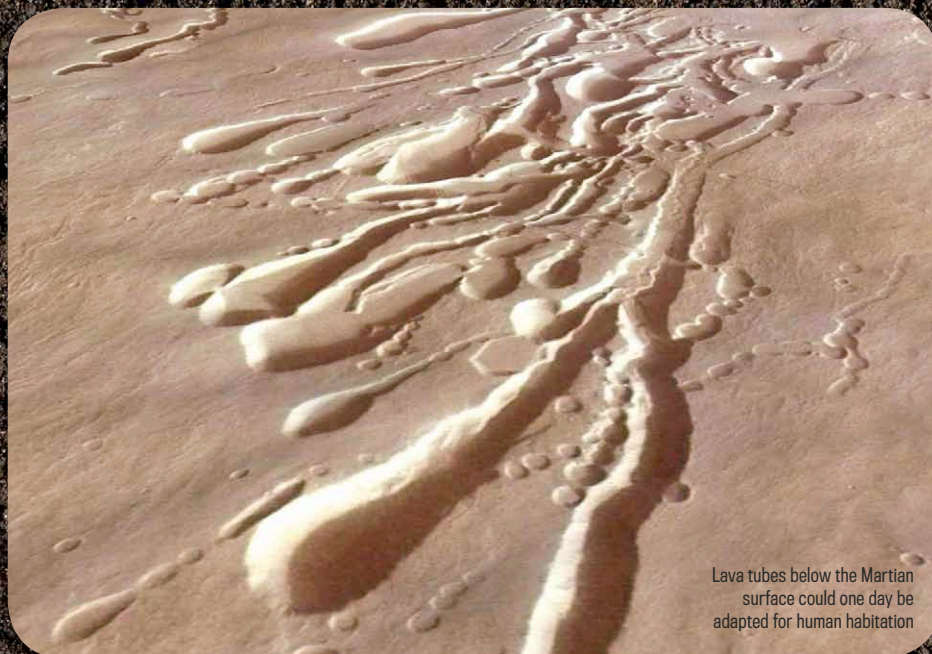
Future space colonies could be housed inside natural caves

ON EARTH, UNDERGROUND development is a smart solution to surface space limitations. In space it could be critical to survival.

Prof Penelope Boston at New Mexico Tech, USA has spent much of her academic life studying how we could live in space. "The first paper I ever published, in 1981, was on inflatable surface greenhouses on Mars," she says. "But I've got a lot smarter now. I've learnt how we should live on another planet - and underground is the way to go."

A key motivation is the high cost per kilogram of taking anything into space. "It's important to become a little more creative," says Boston. "Whatever you can use in the intrinsic environment is a boon."

Cave-like 'lava tubes' on the Moon and Mars are one geological structure being considered for human settlement. Lava tubes are long horizontal tunnels through which lava once flowed. Vertical tunnels known as skylights lead into the tubes, which Boston suggests could contain a lift and be accessed via an airlock. To adapt the tunnels for habitation, Boston says they could be lined with a foam which smooths out the interior contours. "This foam becomes rigid and then the tube can be lined with other things," she says.



Lava tubes below the Martian surface could one day be adapted for human habitation

As well as reducing requirements for building materials, underground living would also provide a ready-made shelter from the brutal surface radiation. "The Moon has no atmosphere to speak of, and Mars has a very thin atmosphere but no magnetic field, so it can't protect itself like Earth does against solar flares and radiation," explains Boston. "But the few metres of rock that you would have above you in a lava tube would provide free radiation shielding."

Prof Boston's team have also considered the possibility of going underground on asteroids. "Recent missions have shown that they're a lot more geologically evolved bodies than we'd thought. So perhaps the possibility exists there for some sort of cave structure," she says.

All this means that the classic science fiction image of inhabited domes on a distant world is unlikely to come true. Instead, our space colonists are more likely to live tucked away inside holes in the ground.

emeritus at Louisiana Tech and an expert on underground space, suggests that subterranean living need not be psychologically problematic at all. "The vast majority of people have no problem taking the London Underground or being in a windowless space for a concert," he points out. "If people see a reason for it, or if there are physical advantages to being underground, then they can accept it."

## HOT STUFF

Issues of psychology aside, the engineering challenges involved in building cities beneath the surface vary depending on the depth of the city. Dr Paul Younger, Professor of Energy Engineering at the University of Glasgow, points out that the first few tens of metres below the Earth's surface tend to have the same average temperature as that found at the surface. So any deep-dwellers in the UK and other similarly chilly countries would need year-round heating to cope with an

average 10°C temperature. Digging deeper, temperatures increase and, depending on location, at a depth of around 500m a positively balmy 25°C may be found. But this comes at a price.

"You're bound to be below the water table then," says Younger. In many locations the water table is just 10 or so metres deep. Keeping the water out, and clean air for breathing in, will require constant pumping.

Applying brute force to dig out a space and continual power to keep it liveable is also expensive. "We can do it," says Younger. "If you want an engineered underground space I'll make you one. But it's not going to come cheap."

Clearly the bigger the underground community, the bigger the headaches. Nuclear energy could provide the power. But there would still be big issues with waste treatment and disposal. "Large communities living underground, independent of the surface, would be very hard to realise," says Sterling.

"It's easier to consider either certain functions located underground interacting with other surface facilities, or certain communities moving underground and being able to exist independently of outside resources for limited periods."

Even if we're not moving entirely underground, it seems an increasing proportion of urban life is set to be lived out beneath the surface. "With massive urbanisation you have two choices," says Hashash. "You can go up, or you can go down. We're seeing an enormous rise in use of underground space. I expect it will grow and grow." ■

DANIEL CRESSEY is a reporter for *Nature*

### Find out more

**BNKR Arquitectura**

[www.bunkerarquitectura.com](http://www.bunkerarquitectura.com)

**New York's Lowline park**

<http://thelowline.org>



# 10 MOST ANNOYING NOISES

Dr Harry Witchel sticks in his ear plugs and shares his list of the most irritating sounds according to science...

## 10 PERSISTENT MUSIC LATE AT NIGHT

ONE OF THE most widespread complaints received by the Noise Abatement Society concerns loud music being played by neighbours at night. For the party-goers the music is pleasurable, while for the complainants it is unbearable. Context and control determine how people emotionally interpret the soundscape; a 'noise' can be thought of as a sound that is out of place. People can be sensitised to a persistent sound that is out of their control, even if the sound is quiet — this is why some people find a dripping tap so grating.



## 9 VICIOUS DOG BARKING

A DOG'S BARK has almost everything: it can be loud and surprising, it has associations with danger and threat. People's mental connections to the sound of a dog barking make them feel bad, because vicious dogs conjure up unpleasant memories. The actual sound itself is also irritating because of its rough quality; for most sounds, roughness makes the sound more grating. Acousticians define roughness as rapid fluctuations in how powerful a sound is (20–200 cycles per second). The fluctuations have to be fast enough that they are heard as part of the sound's texture, rather than as individual changes in the sound's loudness.

## 8 THUNDER

THE MAIN REASON thunder is so frightening to small children is because it suddenly becomes so loud. Similarly frightened responses can arise from fireworks or loud gun shots. Any sound can be aversive if it is loud enough. The cochlea, the sensory organ for sound in



the inner ear, can be damaged by loud sounds. As the amplitude of sound waves in the cochlea approaches the threshold for this damage, the sounds cause pain.





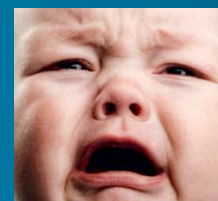
## 7 FLATULENCE

VOLUNTEERS IN AN experiment by Trevor Cox at the Acoustics Research Centre at the University of Salford ranked the noise made by a whoopee cushion as one of the most irritating. It's not loud but its association with embarrassment is likely to be the root of its annoyance. Some sensitive souls find the sound of flatulence unpleasant to hear – although for many flatulence is a staple of comedy, from Benny Hill to *Blazing Saddles*. In Japan, women in public toilets found the sound of urination so embarrassing that they would run the electric hand driers to mask the tinkling. The Japanese solution has been to pipe Barry Manilow records into public loos.



## 6 BABY CRYING

EVOLUTION HAS MADE us particularly sensitive to the sound of a baby crying. The sound spectrum of crying is composed mostly of frequencies from 2,000 to 4,000 cycles per second. These frequencies are perceived as 'sharp', an unpleasant acoustic property. The evolutionary reason for being more sensitive to sharp and rough sounds is probably so that we are roused to action by human shrieks and babies crying.



## 5 WOMAN SCREAMING

THE SOUND OF a woman screaming is even more upsetting than a baby crying. Evolutionarily, this alarm call would highlight danger to the tribe, in order to attract aid or instigate retreat. In one of my own experiments, participants occasionally smiled at a female scream because it reminded them of horror movies. This probably happens because cultural associations can reverse the alarming effects of a piercing scream.



## 4 KNIFE ON A BOTTLE

IN A STUDY of piercing sounds by Dr Sukhbinder Kumar and his colleagues at Newcastle University's Medical School, the noise of a knife scraping a bottle was rated as even more annoying than fingernails on a blackboard. Other sharp and rough sounds that have been rated as highly irritating include railroad brakes, grinding machinery and a metal rake against a slate stone.



## 3 FINGERNAILS ON A BLACKBOARD



THIS IS A grinding sound in the frequency range associated with sharp noises. However, sharpness alone is not what makes this sound excruciating. It's also very rough. The effect of nails on a blackboard is very difficult to reproduce with a recording, so although many lab studies using recorded sounds find this sound to be less annoying than others, it's often reported to be individuals' number one hated noise.

### WHAT DO YOU THINK?

What noises bug you? Have we missed a sound that irritates you? Let us know your opinions on [twitter.com/sciencefocus](https://twitter.com/sciencefocus) (#annoyingnoises) or email us at [reply@sciencefocus.com](mailto:reply@sciencefocus.com)

DR HARRY WITCHEL is the author of *You Are What You Hear* (Algora Publishing, £14.30). He is Discipline Leader in Physiology at Brighton & Sussex Medical School, where he researches the effects of music and noise.



## 2 MICROPHONE FEEDBACK

WHEN YOU HEAR the high-pitched sounds of microphone feedback, does it make the hair on the back of your neck stand up, or do you just want to stick your fingers in your ears? Of all the sharp noises reproduced in the lab this is loudest and sharpest and, when tested, a University of Salford experiment rated it number two for horribleness.

## 1 VOMITING

DOES THE SOUND of vomiting make you feel queasy? In a study of 385,000 internet responses to 34 unpleasant sounds, vomiting was rated as the worst. The sound of vomiting is so nauseating because of your mental associations to it. It brings up people's most repulsive feelings of bodily discharge – in all its unhygienic glory. Interestingly, the acoustic properties of vomiting are not particularly noxious: it is neither rough nor sharp. Sensations associated with disgust are especially well learned by mammals because this skill is necessary to avoid poisonous foods.





# IN THE EYE OF THE SWARM

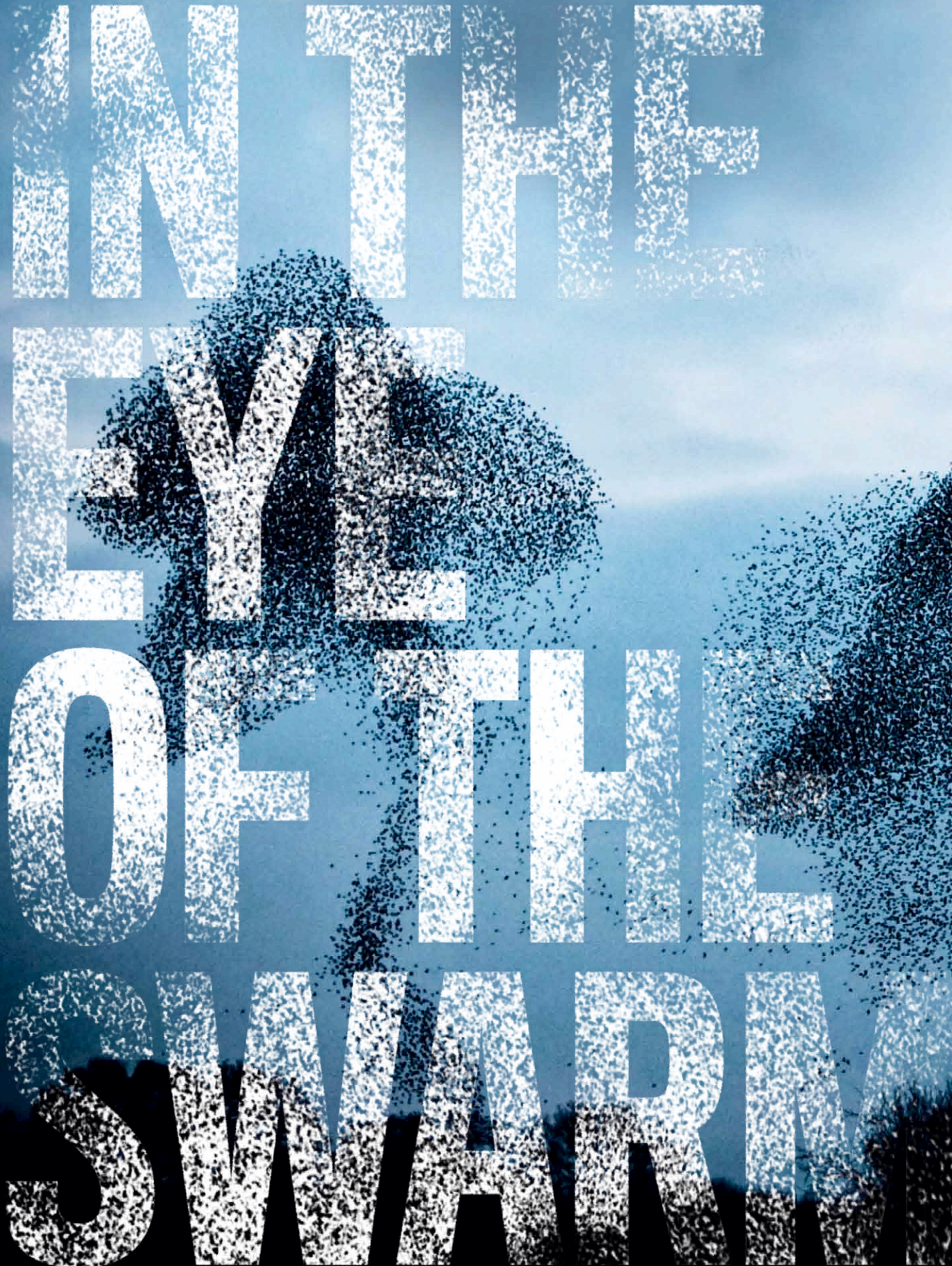
A large flock of birds, possibly starlings, is captured in mid-flight against a clear blue sky. The birds are densely packed in some areas, creating a dark, textured mass, while in other areas they are more spread out, showing individual silhouettes. The overall composition is dynamic and emphasizes the collective movement of the swarm.

PHOTO: ALAMY





Watch *Swarm Chaser* with  
DR GEORGE MCGAVIN  
on BBC TV this summer

Starlings in a 'murmuration'  
- a flock with thousands of  
members - creates fluid,  
unusual shapes

Insights into the  
collective minds  
of swarms could  
transform everything  
from cancer treatment  
to social networking

Words: Jo Carlowe

**B**IRDS DO IT. Bees do it. Fish do it. And even bacteria do it. They all congregate in large groups that take on a sophisticated behaviour of their own. They become a super organism in which the whole is much greater than the sum of the parts. While we give this collective behaviour different names, such as flock or herd, depending on the species involved, it is fundamentally a swarm.

Most of us have encountered a swarm at some point: an acrobatic mass of starlings in the early evening, or a flock of sheep moving across a field. It's

hard not to imagine that there's some kind of telepathic connection between the participants that enables them to coordinate their movements.

Biologists have been able to understand the behaviour of individuals and small groups for decades, but unpicking how individuals form a large collective and how they stay together in their incredible formations has proved more problematic.

Now, with new imaging techniques that allow many individuals within a swarm to be tracked simultaneously, new statistical techniques and powerful





# SWARMS EXPLAINED

Different species have different motives to swarm – and different ways of sticking together



## Starlings

Swarming affords starlings safety in numbers from predators. They also swarm to keep warm and to exchange information about feeding areas. Scientists used to think starlings tracked their immediate neighbours when swarming, but new observation techniques reveal that each bird tracks seven others.



## Ants

Individually ants aren't particularly smart creatures, but as a colony, swarm intelligence enables them to find the quickest path to food, overcome obstacles and outwit predators. They do this by using pheromones to communicate the optimal path to any point or signal danger.



→ volumes of data involved, scientists are coming to understand swarming like never before. And this understanding will have pay-offs in fields far removed from behavioural science.

## SIMPLE BEGINNINGS

The first attempt to get to the bottom of swarming using computers came back in 1986. Graphics expert Craig Reynolds, then working for Symbolics Inc in the US, developed a computer model of bird flocking. In his model, his creatures were called 'boids' – a play on the pronunciation of birds in a stereotypical New York accent – and he made them move according to three simple rules. Each boid would steer to avoid getting too close to its immediate neighbours. Each would follow the average heading of its local flock mates, and each would steer towards the average position of its flock mates.



Swarming bees were filmed in hi-def for Dr Passino's study

Reynolds found his boids' collective behaviour was remarkably close to flocks of birds seen in the natural world. In fact, a modified version of his model was used to create bat swarms and penguin flocks in the 1992 film *Batman Returns*.

In the real world, the basic rules of swarm behaviour are similar to those adopted by Reynold's boids. But each species has its own way of coordinating the swarm – and its own motivations for forming them in the first place (see 'Swarms explained,' above).

The subtleties of swarm behaviour are still the subject of extensive research, and the insights are often coming from people who, like Reynolds, are as at home with engineering and computer software as they are with the natural world.

Dr Kevin Passino, Professor of Electrical and Computer Engineering at Ohio State University, is a good example. He worked with fellow Ohio engineer Kevin Schultz and Cornell neuroscientist Tom Seeley to film a bee swarm in high definition – no mean feat, given that a swarm's path is so unpredictable. They did this by transporting a colony of bees to Appledore Island off the coast of Maine, which has virtually no high vegetation for swarms to settle on. They then got the bees to swarm from a stake to a comfy nesting box.

By analysing over 3,500 frames, they were able to build a picture of the movement of many of the individual bees.

It was already known that 'streaker' bees who scout for new nesting sites perform a dance to relay their preferred location, but it was unclear how these bees led the rest of the colony to that site. "We found that the streaker bees just fly fast and the other bees see them and chase them, and so head in the right direction," says Passino.

He is currently studying how bees forage for nectar, behaviour that may in future be replicated in a swarm of another kind – autonomous flying vehicles. It

## THE SWARM CHASER

Entomologist Dr George McGavin recalls some close encounters while filming his new BBC series

“While filming *Swarm Chaser*, I ticked several things off my bucket list. With the help of Californian bee scientist Professor Norman Gary, I got the chance to be covered in live bees. When a honey bee colony grows too large, more than half of the workers will leave with the old queen. They form a swarm on a branch and while scout bees look for a new home, the rest cluster together around the queen. Norm applied some queen odour to my clothes and began to move a swarm from where they were resting to me. Eventually, I was covered from the waist up in tens of thousands of bees. It felt a bit like wearing a gently-vibrating, furry hooded top.





### Wildebeest

Wildebeest migrate annually to new pastures. This looks like a frenzy of mass movement but scientists now know they are using 'swarm intelligence', systematically exploring and overcoming obstacles as one. Swarming is also protective as it's harder for a predator to take out a young animal when it runs in a group.



### Fish

Fish swarm together defensively to avoid predators. In studies on 'golden shiners' the fish move away from light to safer dark areas. No single fish purposely swims towards darkness, but the fish innately swim slower in shade, causing others in the group to decelerate until everyone is in the dark.



turns out that bee swarms allocate the optimal number of individuals to different areas to maximise the pay off. Replace bees with tiny flying vehicles, and nectar with missing hikers, and the benefits of mimicking their behaviour are obvious. "If you use the 'algorithm' bees use when they're foraging, you come up with a very effective strategy to allocate vehicles to the most profitable search areas," says Passino.

The military have long been working on robot swarms, but most are programmed

to receive commands centrally. To simulate nature, each tiny craft needs to independently take cues from its neighbours and adopt the bees' instinctive foraging 'algorithm'. Passino believes this is still 10 years away.

But when it comes to swarming it seems that some of the smallest lifeforms – bacteria – are the most sophisticated. Although it may sound surprising, these microbes do swarm – grouping for protection or forming 'traffic lanes'.

"Some bacteria are like explorers and move more," say Prof Eshel Ben-Jacob at the School of Physics and Astronomy at Tel Aviv University in Israel. "Some are like builders. As they move, some of the explorers turn into builders to mark the boundaries of the trail for the bacteria coming later to follow."

This may sound similar to ants, who mark their route with pheromones, but bacteria are actually superior. Ants' pheromone messages cannot be



When bees swarm they are very placid. They have no brood or food reserves to protect and as long as you move carefully, all should be fine. I only got one sting.

We also filmed how scout bees communicate the suitability of a new home to their nest mates by performing a waggle dance. We provided three new homes but only one was ideal. The scouts returning from the best home danced more vigorously and for longer. More scouts went to this location and reported back in a similarly enthusiastic manner. Eventually a tipping point was reached and the whole colony moved *en masse*.

I also got to witness the annual migration of Red Crabs on Christmas Island. They return to the Indian Ocean each year to spawn and with millions of females shedding 100,000 eggs each, the sea turns brown with trillions of larvae. Even with this mass spawning, most will end up as food for other creatures. ”

Dr George McGavin is a Research Associate at Oxford University Museum of Natural History



Dr George McGavin sports the asymmetrical bee snood - this season's must-have fashion item



## THE DARK SIDE OF SWARMS

Plagues of locusts have wreaked havoc for centuries – but science may soon be able to stop them

In the spring of 2013, a swarm of locusts raged across Egypt. The timing couldn't have been more apposite – they struck close to Passover, the festival that retells the Biblical story of the Israelites escaping the Pharaoh through a series of plagues, one of which was a plague of locusts.

The swarm contained over 30 million insects, damaging crops southwest of Cairo. A similar swarm in 2005 destroyed 40 per cent of Egypt's crops. In an attempt to prevent similar devastation, planes were scrambled to dust the fields with pesticides but it was a case of locking the door after the horse had bolted.

But scientists believe in the future agricultural experts will be able to prepare for swarms in advance due to an increased understanding of how and why locusts shift from a solitary phase to 'a gregarious phase' in which they act as a mass.



Locust swarms have traditionally spelled disaster for farming communities

Using computers to map the position and orientation of locusts, Princeton University's Prof Iain Couzin has found that they form swarms when they run short of nutrients, with a low-protein diet turning them into cannibals.

Couzin has found that individual locusts surge forward whenever they feel another locust bump against them to protect themselves from being eaten. In turn, they then try to eat the locust in front, providing

the impetus for the swarm to keep moving. By better understanding the "biological drivers of swarms," Couzin says it will be possible to use satellite imaging to estimate the distribution and nutritional quality of vegetation to predict when and where locust swarms may form, and so allow more effective preventative measures to be taken.

The technology has yet to be put into place but Couzin believes it's only a matter of time.

➔ changed once the ant has moved on – bacterial messages can. As well as secreting chemicals to mark their trail, live bacteria are left along the way to form boundary walls and to act as 'look-outs'. If these encounter a problem, they can send chemical signals to their neighbours.

Bacterial swarm intelligence is attracting interest in unexpected places. Google recently invited Ben-Jacob to discuss how bacterial communication could be adapted to social networking, where new links are often stymied by language barriers. "A bacterial colony is composed of a diversity of cells, each with somewhat different communication capabilities," says Ben-Jacob. "It can be viewed as a human community of people with different dialects. Efficient communication in such a community

requires that each individual has what is termed 'linguistic plasticity' – the ability to understand diverse dialects. While bacterial language does not have advanced grammar, it has high linguistic plasticity."

Perhaps most exciting are the implications that bacteria swarming methods have for medicine. "Cancer uses the same basic mechanism as bacteria to navigate through the body. It even uses the same molecules to communicate. Once you understand the principle of communication, you can act against it."

## HUMAN SWARMING

While understanding bacterial swarming will provide new cancer treatments, the 'swarming' of humans themselves is also coming under the spotlight. Professor Iain Couzin, a Princeton University ecologist and a world leader in swarming research, is applying the same techniques he uses to see patterns in locust swarms and fish shoals to see what goes on in crowds. "The modelling and tracking is very similar – we use the same computer code," says Couzin.

"By determining the way we move and interact in crowds, we can develop simulations that reproduce important aspects of crowd behaviour like evacuation from buildings," Couzin says. It's an approach that's already paying dividends. In one test at Hull and Leeds universities, people were found to be more likely to follow leaders if those leaders were

## "Cancer uses the same basic mechanism as bacteria to navigate through the body"

grouped together rather than spread apart. "In close proximity, their influence is mutually reinforced," says Couzin.

Unlike bees and bacteria, we humans did not evolve to live in large groups. So by better understanding the group behaviour we have adopted, we can fix things when it goes wrong. And by understanding the actions of species more adept at group behaviour, we can benefit from their collective brilliance. ■

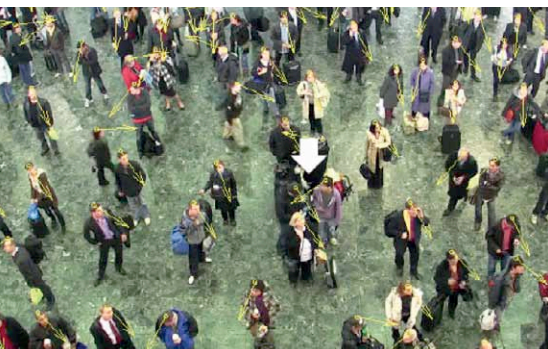
Jo Carlowe is a science writer and author, with a background in psychology

### Find out more

//BBC LOGO// **Swarm Chaser** with Dr George McGavin is coming to BBC TV this summer

<http://bit.ly/ZRdW1i>  
Big Think interview with Prof Iain Couzin

PHOTO: GETTY, ANDREW C GALLUP/IAN D COUZIN



Methods used to study animal swarms can also be applied to the behaviour of human crowds





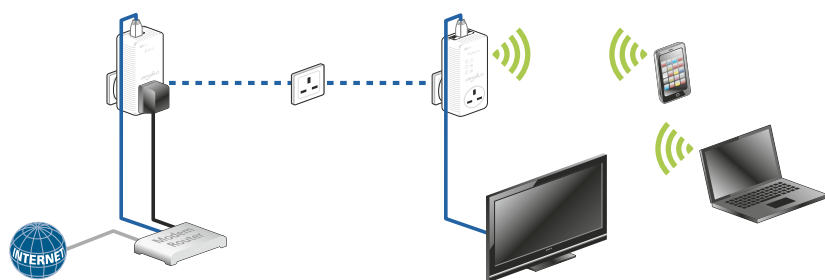
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# Q&A

## YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



**SUSAN BLACKMORE**

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



**DR ALASTAIR GUNN**

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



**ROBERT MATTHEWS**

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



**GARETH MITCHELL**

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service

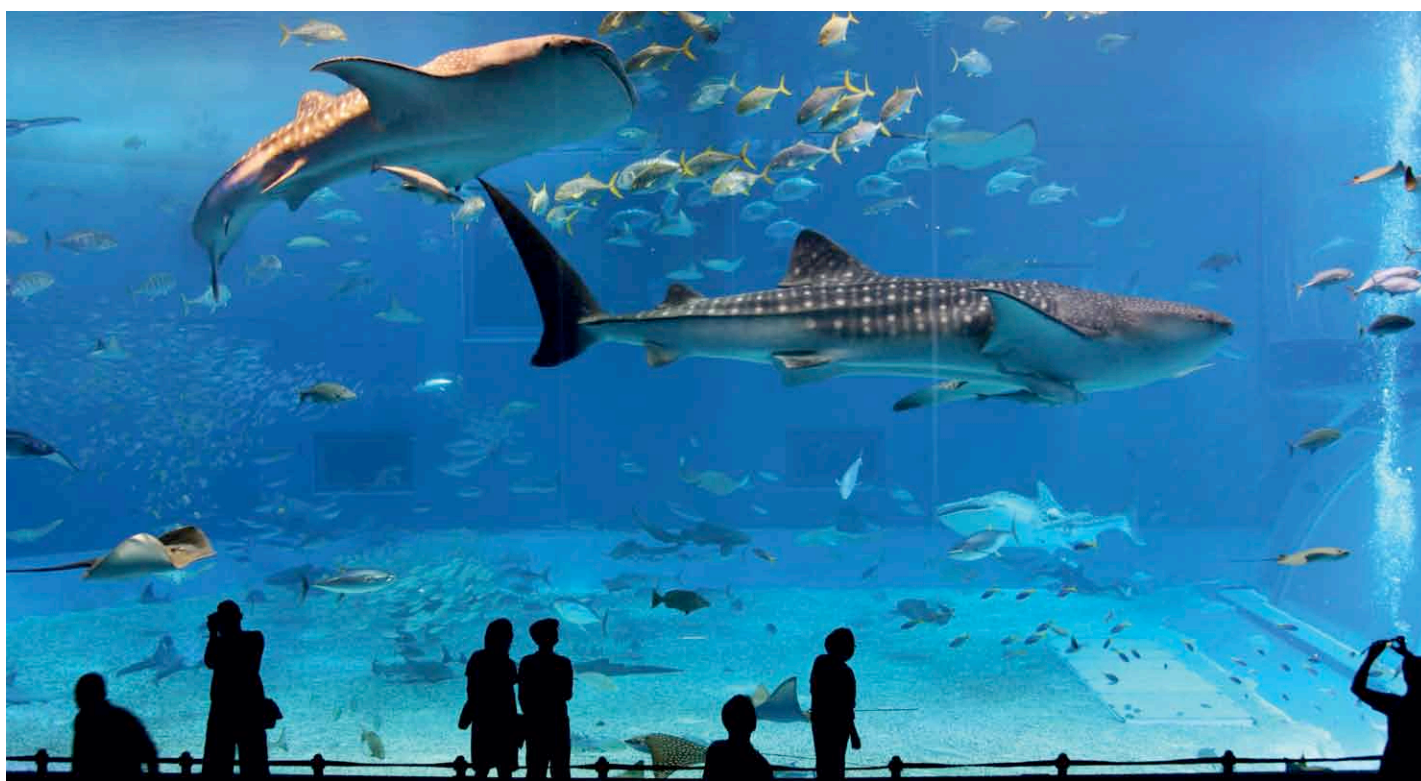


**LUIS VILLAZON**

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

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or post to *Focus Q&A*, Tower House, Fairfax Street, Bristol, BS1 3BN



มอว.บอจนิลพวากอจ

**SAM LIPLEY, BRAUNTON**

### How thick is aquarium glass?

**A** A LARGE PUBLIC aquarium, like the one pictured above in Okinawa, Japan, can contain 7.5 million litres. That's more than 7,500 tonnes of water, held back by a single window 22.5m across. Glass isn't actually very suitable for a window this large. It is brittle, so it

needs to be very thick to stop it from shattering and at such thicknesses, the high refractive index of glass distorts the view of the fish in the tank.

Instead, polymethylmethacrylate (PMMA) is used. This is also known simply as acrylic or by its various trade

names, such as Plexiglass and Lucite. PMMA is half the density of glass and has twice the tensile strength. It also flexes and has a lower refractive index. This allows the aquarium window to be thinner and give a clearer view. Even so, the aquarium window above is 60cm thick. **LV**

Don't tap the polymethylmethacrylate!  
Behind it is the world's biggest shark  
- the whale shark - at Osaka  
Aquarium Kaiyukan, Japan

PHOTO: JON RAWLINSON



## In Numbers

400,000

tonnes of carbon dioxide is pulled from the atmosphere each year as a result of iron-rich whale poo stimulating the growth of plankton that feast on the greenhouse gas.

Q JOEL PICKUP, MANCHESTER

## What is fire like in zero gravity?

**A** THE ABSENCE OF gravity has a peculiar effect on the flames making up a fire. The ribbon-like shape they have on Earth is the result of the rising current of hot air, which is less dense than the surrounding air. As such 'convective' effects can't exist in zero gravity, so flames take on a blob-like appearance instead. **RM**



Flames: not as dramatic in space as they are on Earth

Q DANNY LLOYD, WITNEY

## Will physics find anything smaller than a quark?

**A** ATOMS WERE SUPPOSED to be fundamental, but it's now known they too contain particles – protons and neutrons – which themselves contain particles called quarks. Theorists have postulated the existence of 'preons', particles inside electrons and quarks, but so far no compelling evidence for their existence has ever been found. **RM**

Quarks could look like beautiful marbles... maybe



Is gum the secret of Alex Ferguson's title-winning success?

Q SIMON VINCENT, KING'S LYNN

## Can chewing gum help you concentrate?

**A** YES, AMERICAN SOLDIERS have been routinely issued with gum to improve concentration and relieve stress since the First World War and several studies have since demonstrated that it improves performance in both visual and audio memory tasks. Exactly how it helps still isn't clear though.

One possibility is that the physical chewing action helps to stimulate the blood flow to the brain, but tests where volunteers chew with an empty mouth don't show the same benefit. It may be that the tongue and jaw manipulation involved in moving gum around your mouth occupies parts of the brain that might otherwise get distracted. **LV**

Q ANDY LANE, READING

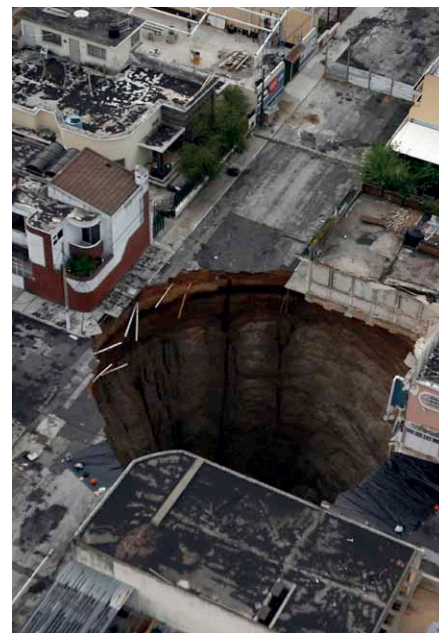
## How do sinkholes form?

**A** THERE ARE TWO main processes. Either a cave gradually enlarges until the roof falls in, or a top layer of sand and soil is washed by rainwater into fissures in the underlying rock, eroding it away before it collapses leaving a hole.

Both kinds are normally found in limestone areas because limestone is slightly water soluble and forms the kind of caves and fissures that are required. Sinkholes can be triggered by sudden storms or flash floods and are also sometimes the result of old mine works.

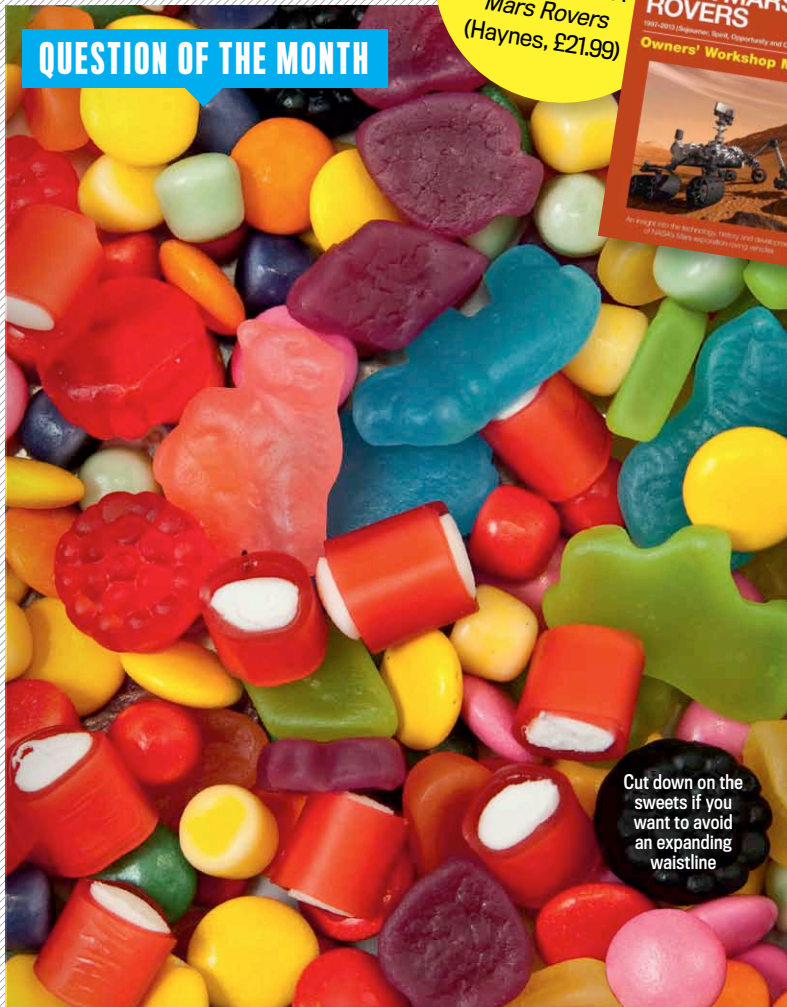
Florida is particularly prone to sinkholes because of an underlying system of limestone caverns, while in 2010 a sinkhole in Guatemala City was big enough to swallow a road and an accompanying three-floor building. **LV**

A sinkhole in Guatemala City  
Should have had a survey done...





## QUESTION OF THE MONTH

**WINNER!**Christoffer wins  
a copy of *NASA Mars Rovers*  
(Haynes, £21.99)Cut down on the  
sweets if you  
want to avoid  
an expanding  
waistline

Q CHRISTOFFER SODERBERG, BY EMAIL

## Why have we evolved to love the taste of unhealthy foods?

**A** BECAUSE WE DIDN'T evolve in a world full of sugar. For our ancestors in Africa, sugar from ripe fruit or a precious bee hive would have been a rare treat, and well worth prizing for its energy value. Those who liked the taste and ate the sugar might have gained an advantage and so passed on their 'sweet tooth' through their genes.

Today sugar is in nearly all processed foods as well as readily available sweets, jams, biscuits and fizzy drinks. Sugar is unhealthy

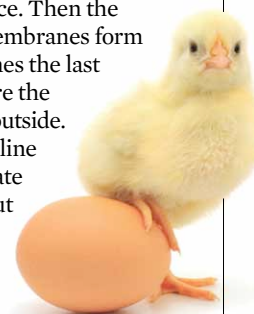
because it causes an increase in the hormone insulin in the bloodstream. This in turn causes the body to switch over from burning fats to burning sugar and sending the fat into storage. So eating sugar makes you fat. In large quantities it disturbs the natural role of insulin, ultimately leading to diabetes. Even worse, we quickly adapt to the taste of sugar and need more to get the same pleasure. So we can become addicted in a way that was simply impossible for our ancestors. **SB**

Q LUCY CROFT, LEEDS

## How does an egg form inside a chicken?

**A** THE PROCESS BEGINS with an oocyte or egg cell produced in the hen's ovary. This moves down a spiral tube called the oviduct where it may be fertilised. However, even if it is not fertilised, the process continues so that hens can lay unfertilised eggs, including most of those we eat. Next the vitelline membrane forms around what will become the yolk, structural fibres start forming, and then layers of albumin that will become the egg white.

As the developing egg moves on down the spiral tube it rotates, twisting the fibres that hold the yolk in place. Then the inner and outer shell membranes form and the egg finally reaches the last part of the oviduct where the shell is deposited on its outside. This is made of a crystalline form of calcium carbonate called calcite. After about a day, the egg is pushed out through the vent and is finally laid. **SB**



Q KATE TUTTLE, CANTERBURY

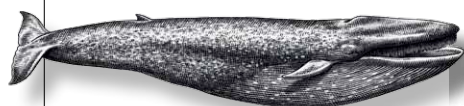
## Is shortwave radio still in use?

**A** Yes it is. For example, the BBC World Service still broadcasts in shortwave from the Ascension Island relay in the Atlantic off the coast of West Africa. The shortwave band is from around 3MHz – 20MHz. At these frequencies, the signals bounce off the Earth's upper atmosphere, meaning that a single transmitter can cover areas thousands of kilometres across. Other BBC shortwave stations cover more of Africa, as well as large regions of Asia, Middle East and Gulf states, Afghanistan and Iran. **GM**





# TOP TEN HEAVIEST WHALES



**1. Blue whale**  
170 tonnes  
Largest known animal ever to have existed



**2. Fin whale**  
120 tonnes  
Feeds in groups of up to 300 individuals



**3. Bowhead whale**  
100 tonnes  
Has the largest mouth of any animal



**4. North Pacific right whale**  
80 tonnes  
Most endangered whale on Earth



**5. North Atlantic right whale**  
70 tonnes  
Forty per cent of its weight is blubber



**6. Sperm whale**  
57 tonnes  
Has the largest brain of any animal



**7. Southern right whale**  
47 tonnes  
Has the largest testes of any animal



**8. Humpback whale**  
40 tonnes  
Produces a complex song that lasts up to 20 mins



**9. Grey whale**  
36 tonnes  
Has the longest migration of any marine mammal



**10. Sei whale**  
28 tonnes  
Can reach speeds of 50km/h over short distances

PHOTO: GETTY, LUCASFILM/20TH CENTURY FOX/KOBAL, PRESS ASSOCIATION, ALAMY X2



Pick a different sport if your brain keeps experiencing a sudden lack of chemical energy

**Q ROBERT EAST, PETERBOROUGH**

## Why do people go unconscious when they bang their head?

**A** THE EFFECT OF even minor impacts on the brain is barely less dramatic than what you'd expect from dropping a laptop from head-height, and it's amazing that most people recover so quickly. The physical jolt damages the brain's cell walls and stretches the axons connecting the neurones, destabilising the normal flow of

neurotransmitters and causing potassium ions to flood out of cells and calcium ions to flood in. This triggers a sudden demand for chemical energy which the brain struggles to provide – especially if there's been a loss of blood. As a result, the brain can run out of energy and close down – triggering unconsciousness. **RM**

**Q CAREL LUCAS, PERTH, AUSTRALIA**

## Why do women live longer than men?

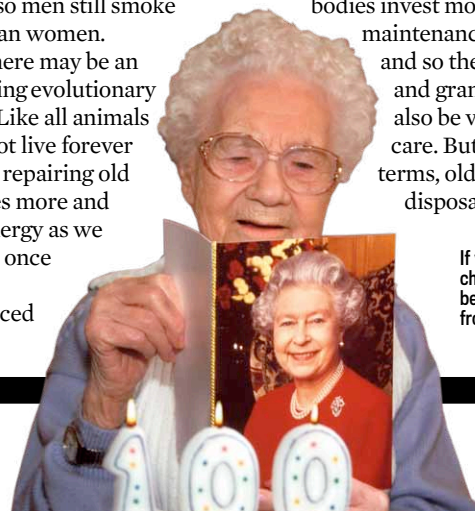
**A** ONE REASON IS that men are more prone to heart disease. This may be because women have lower levels of iron since they lose blood through menstruation, or it may be the damaging effects of variations in testosterone in young men. Also men still smoke more than women.

But there may be an underlying evolutionary reason. Like all animals we do not live forever because repairing old cells uses more and more energy as we age, and once we have reproduced

our bodies have effectively done their work as far as the genes are concerned. So keeping an old body going is only worthwhile if it can help the next generation. Mothers' essential role in bringing up children may mean that their bodies invest more in

maintenance than men's do, and so they live longer, and grandmothers may also be valuable in child care. But in biological terms, old men are disposable. **SB**

If you're male the chances are you won't be receiving good wishes from Her Majesty





Laser weapons will only come of age when they're attached to giant robotic horses



**Q** ED CLARK, ROTHERFIELD

## Could lasers be used as weapons like in *Star Wars*?

**A** A HIGH-ENERGY laser weapon strips electrons from atoms in the air, forming an ionised channel along which intense pulses of electromagnetic radiation are directed at a target. Trials have not been quite as dramatic as the Millennium Falcon quad-laser

canon, but the US Navy Maritime Laser Demonstrator incinerated the engines of a target vessel from a few hundred metres away. And in Switzerland, a company called Rheinmetall brought down an aerial unmanned vehicle using a ground-based 10KW laser weapon. **GM**

### WHAT IS THIS?



#### KNOW THE ANSWER?

Go to [sciencefocus.com/qanda/what](http://sciencefocus.com/qanda/what) and submit your answer now!

#### LAST MONTH'S ANSWER:

Air bubbles in a glacier's cryoconite hole, guessed by Tony Cerbone.

**Q** COLIN CURRAN, IRELAND

## Why don't ice-skaters get dizzy?



Figure skating: a good reason not to have a Vindaloo the night before

**A** DANCERS AVOID DIZZINESS when pirouetting by keeping their eyes locked on a fixed point and then whipping their head around quickly when they can't twist their neck any further. Ice skating spins are much too fast for this to be possible or safe, though. Instead it's mainly a question of keeping the eyes horizontal, so the view only spins around one axis, and gradually training to overcome the dizziness through long practice. Many figure skaters will incorporate a dance move at the end of a long spin that is designed to provide a breather while the dizziness passes. **LV**

### ? Did you know?

The smallest bird's eggs are laid by the Vervain Hummingbird. Its tiny eggs can measure under 1cm in length.



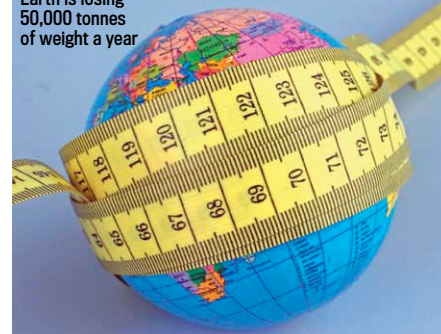
**Q** PETER WRIGHT, EDINBURGH

## Is Earth gaining or losing mass?

**A** SCIENTISTS ESTIMATE THAT the Earth gains about 40,000 tonnes of material each year in the form of dust from space. They also estimate that about 95,000 tonnes of hydrogen gas are lost from the Earth's atmosphere each year. The Earth is therefore losing at least 50,000 tonnes of mass every year.

While this might seem a lot, with a total mass of about 6 septillion kg ( $6 \times 10^{24}$ kg), it would take about 120 thousand trillion ( $1.2 \times 10^{17}$ ) years for the Earth to disappear with that rate of mass loss. That's more than 8 million times the age of the Universe! **AG**

Earth is losing 50,000 tonnes of weight a year



**Q** BEN QUICK, BY EMAIL

## Do other species have different blood types?

**A** YES. BLOOD TYPES are just surface proteins on the red blood cells that trigger the immune system to produce antibodies. Mixing incompatible blood types causes the immune system to clump the red blood cells together. Chimpanzees and gorillas have the same ABO blood types as us, along with some other rarer types. Cats have their own A, B, AB system; horses have A, C, D, K, P, Q, T, U, V and W types. Dogs have more than 13 different blood types, but just two account for most of the population. **LV**



Q MORVEN WALTERS, SHEFFIELD

## How do hot water bottles relieve stomach pain?

**A** THEY MAY NOT. People often say 'stomach' when they really mean abdomen (belly or tummy). The stomach is high up under the diaphragm and can suffer pain through indigestion or more serious conditions such as ulcers or gastritis.

Abdominal or tummy pains have many causes and they can often be helped by a hot water bottle. For example, period pains are caused by temporary reduction in blood flow to the tissues. Warmth from the bottle

is detected by heat receptors that influence the chemical

messengers that signal pain to the brain. Women

can suffer debilitating period pains and a hot water bottle can be a drug-free alternative to painkillers. **SB**



Q RICHARD O'NEILL, GLASGOW

## Would a runner do a mile faster in a straight line than on a running track?

**A** THEORETICALLY YES. RUNNING along the curved part of the track creates asymmetric loading on the legs and requires extra energy to alter the direction of travel. But the effect is very small compared to factors such as wind conditions and the presence of pace setters. The International Association of Athletics Federations only recognises mile races run on tracks. **LV**

Forget about running in a straight line, it's pace setters you need to worry about



Q JOHN CATTEMULL, BY EMAIL

## Why does everything in the Universe rotate?



**A** ALL ASTRONOMICAL OBJECTS are formed by gravity pulling matter together. If a cosmic body originates from anything that had even the tiniest amount of rotational motion originally, this spin rate will only become greatly enhanced as the object collapses. This arises because of the law of conservation of angular momentum. An object's angular momentum is a measure of its resistance to changes in its rotational motion. The more massive an object, the faster it rotates, and the larger it is the more difficult it is to change its spin.

Angular momentum is a conserved quantity so that in the absence of other forces an object's angular momentum will always be the same. So, an increase in an object's radius will slow the rotational rate, and a decrease will quicken it.

In a turbulent and angular momentum-rich Universe like ours, it means everything from dust particles to galaxy super-clusters will have some degree of rotation. **AG**

It's amazing to think that the same forces that have shaped the Universe also make your clothes come out nice and soft

Q SUE MORRIS, EXETER

## Are there storms on the Moon?

Lunar travellers won't need to pack an umbrella



**A** STORMS ON EARTH are created by temperature and pressure gradients in the atmosphere. But with hardly any atmosphere on the Moon (it is 100 trillion times less dense than Earth's), the Moon simply doesn't have weather of any kind.

However, Apollo astronauts in orbit around the Moon often reported bands of light filtering through dust in the lunar atmosphere around the time of

sunset or sunrise. Scientists now believe that between lunar night and day there is a swirling cloud of dust that stretches all the way from the north pole to the south pole. It is probably caused by a small electric field that runs horizontally across the lunar surface between the day and night sides. However, this barely noticeable phenomenon is far from being a 'storm'. **AG**





## HOW IT WORKS

# NASA'S ASTEROID CATCHER

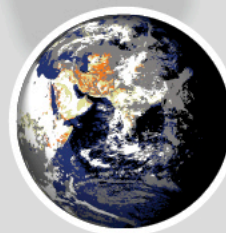
IF YOU'VE EVER struggled to cram all your shopping into a bag to get it home again, then spare a thought for NASA, which is going to need a very big bag indeed for its latest purchase.

In April NASA announced a mission to capture an asteroid and tow it back to Earth, parking it near the Moon. But how do you go about capturing a 500-tonne spinning lump of rock and ice?

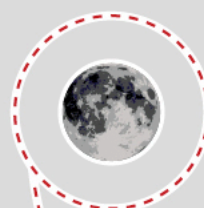
The plan is to send a small, unmanned, solar-powered probe to intercept the asteroid, a journey that will take nearly four years. Once there a high-strength inflatable bag will be deployed around the space rock, held open by four or more inflatable arms linked together with hoops. Cinching cables would then be used to pull the bag up against a ring that constrains the asteroid's position

and attitude. This would bring the space rock's centre of mass close enough to the probe's thrusters that they can then be used to stop the asteroid spinning.

The probe will then park the asteroid at a Lagrangian point (an area of space where the gravity between two masses is balanced) between the Earth and the Moon, to prevent it from wandering off. The asteroid will then be studied by astronauts using an Orion spacecraft, which should be ready to launch by 2021 to meet President Obama's target of landing man on an asteroid by 2025. The craft will have a robotic arm to attach to the asteroid, as the space rock is too small to land on directly. The project will also allow NASA to test measures for diverting future asteroids on a collision-course with Earth.



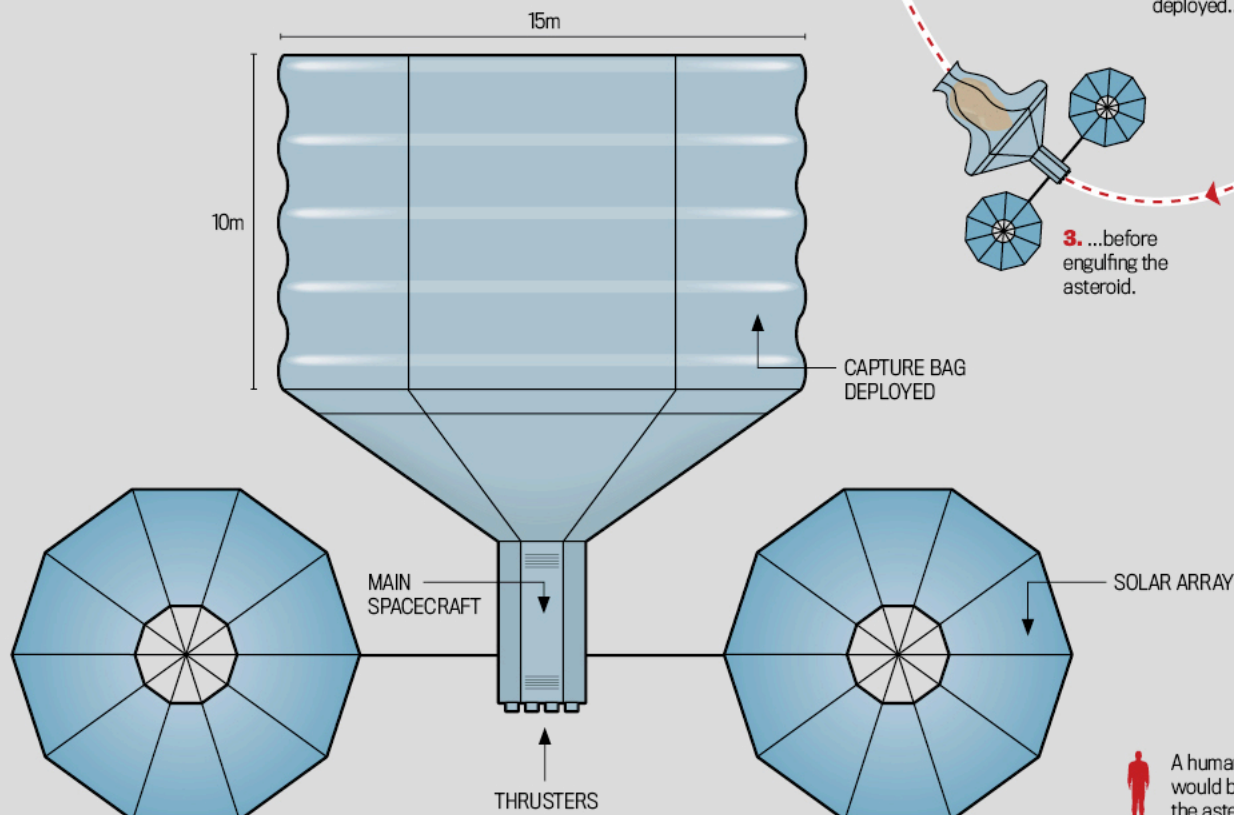
**1.** Following launch the asteroid catcher starts a 2.2 year journey before a slingshot from the Moon sends it into deep space.



**4.** The asteroid is parked in a stable orbit around the Moon after a 2-6 year journey.

**2.** After another 1.7 years the capture bag is deployed...

**3.** ...before engulfing the asteroid.



A human (to scale) would be dwarfed by the asteroid capture



# THE NIGHT SKY: WHAT CAN I SEE IN JULY?

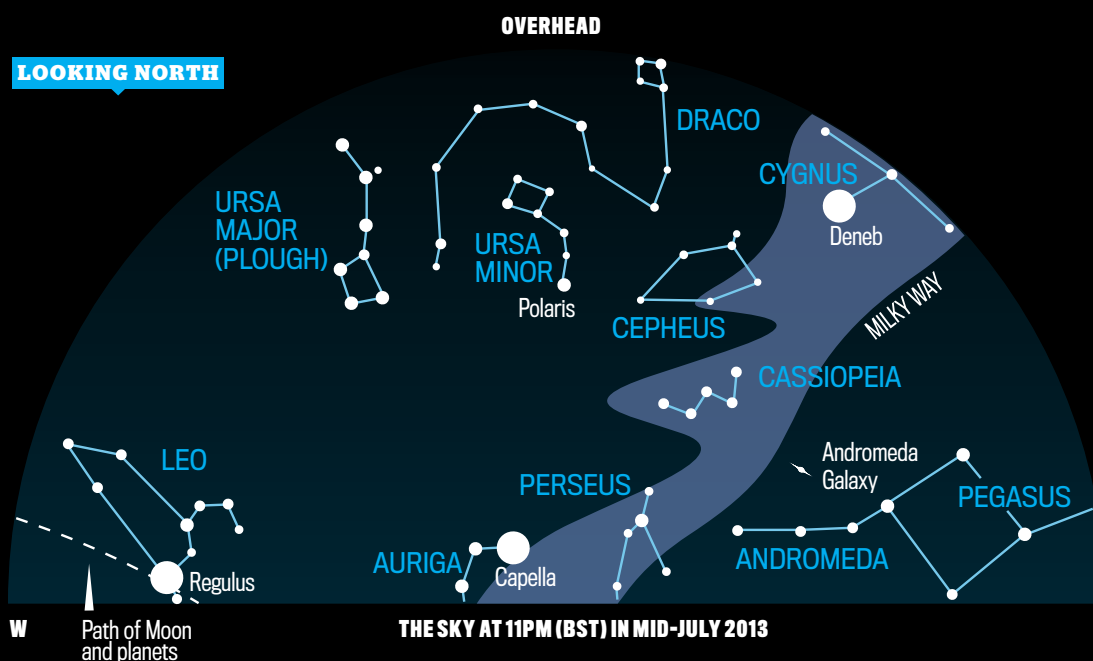
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Astronomy with  
Heather Couper  
and Nigel Henbest



THIS MONTH VENUS hangs low in the evening sunset, while Saturn skulks in the southwest. Early birds can spot Jupiter and Mars having a close encounter on the morning of 22 July. But the drab evening skies are illuminated by twin beacons: the orange star Arcturus high in the southwest, and blue-white Vega almost overhead. Enjoy!

## LOOKING NORTH



## LOOKING NORTH

11 July, 10pm

Tonight, there's a striking tableau as Venus is joined by the narrow crescent Moon. Above the pair, you'll find Regulus, the star marking the heart of Leo (the Lion).

## All month, all night

If you're lucky, you might be able to spot pearly clouds glowing long after the sky has grown dark. The highest clouds in the Earth's atmosphere – some 80,000m up – these 'noctilucent clouds' consist of ice that's crystallised around particles of dust.

## LOOKING SOUTH

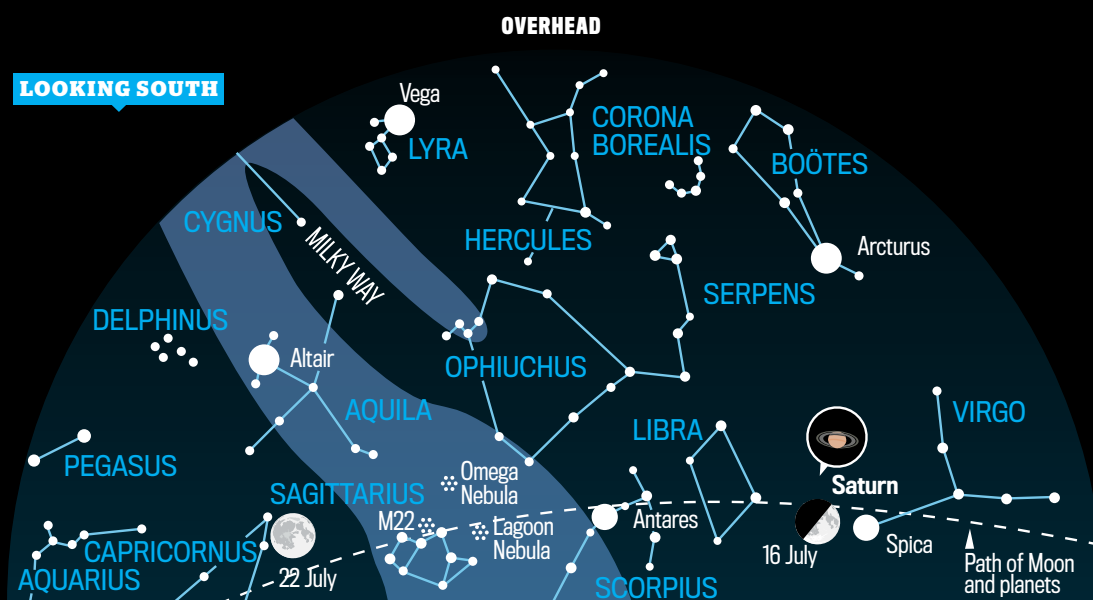
All month, all night

Sagittarius is a treasure trove of faint sights, including the wonderful Lagoon Nebula (visible to the naked eye on dark nights), and also the fainter Omega Nebula and the star cluster M22 (both visible in binoculars).

## All month, all night

Beautiful Vega, the fifth brightest star in the sky, soars overhead. One of our celestial neighbours, only 25 light-years from the Sun, Vega is orbited by a disc of cosmic dust – and possibly planets.

## LOOKING SOUTH



## Find out more



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Q JAMIE GREENAWAY, LONDON

## What's the best method for memorising facts?

**A** TECHNIQUES DESIGNED TO help people remember stuff – ‘mnemonics’ – date back thousands of years, reflecting the fact that the Ancients had far more need for such techniques than we do, with our notebooks and laptops. The best-known method has its origins with the 5th Century BC Greek poet Simonides of Ceos. Asked to identify people crushed by the collapse of a building he had just left, Simonides found he could do so by mentally recalling where each person had



been sitting. This trick of linking facts with locations is still widely used by memory competition contestants, who often call it the Method of Loci (MOL) or ‘mental walk’ (ironically, the connection with Simonides

A competitor tries to memorise a deck of cards at the World Memory Championships... or is he trying to remember where he left his keys?

is widely thought to be just a nice story to help recall how it works).

Brain scans have found that expert memorisers who use MOL have higher levels of activation in areas of the brain linked to spatial awareness, such as the hippocampus, but how this helps with recollection remains unclear. It doesn't just work with ordinary facts, though: in 2009 a US-Canadian team of scientists reported how it could be used to remember tens of thousands of random digits. MOL is also being investigated as a way of combating age-related memory loss. **RM**

Q NICK DAVIES, BY EMAIL

## How do climbing plants climb?

**A** CLIMBING IS A parasitic behaviour that saves a plant the effort of making a strong trunk or stems of its own. There are several distinct strategies. Ivy uses specialised roots that work into tiny fissures in tree bark or a wall, while clematis has leafstalks that twist around the stems of another plant to anchor it as it grows. Cucumber plants have tendrils that wrap around another stem and then pull the plant up by coiling up the tendrils.

Climbing plants normally start by creeping along the floor until they reach a stem. Although the point of climbing is to escape the shade, some tropical climbers begin by growing *away* from the light, because this makes them more likely to reach a tree trunk. Once they touch something, the physical contact triggers chemical changes that stimulate the climbing behaviour and the plant begins to grow against the direction of gravity. **LV**

What eventually happens if you're not much of a gardener



PHOTO: DEMOTIX, THINKSTOCK



Q MARY PEARSON, ANDOVER

## Is my brain more active at night or during the day?

You may be up to more when you're asleep than you think...

**A** A SLEEPING BRAIN is not resting. A 2010 study at Harvard found that the levels of ATP (the chemical used to provide energy to cells) in the brain remain fairly constant while you are awake, but briefly surge when you fall asleep. Rather than resting the brain back to full strength, sleep provides it with an initial energy boost.

This increased energy is used up through the night to create and rearrange the connections between neurones. So while some regions may be less active, your brain uses more energy overall while you sleep. **LV**

Q CHRIS HAYNES, LONDON

## How are our details protected online?

**A** WHEN MILLIONS OF gamers had personal details stolen after Sony was hacked in 2011, many were asking how companies protect confidential data. E-commerce sites employ firewalls and elaborate password systems to block hackers from accessing servers. However, after its 2011 breach Sony admitted that while its credit card data was encrypted, other information was not.

As for the connection between your computer and a shopping site, it's protected using Secure Session Layer (SSL). It's what you see when the padlock symbol appears in your address bar. Under the SSL protocol your browser establishes a secure encrypted connection to the server. An eavesdropper would just see a load of gobbledegook. **GM**



Look out for the padlock symbol to shop safely online

Q PREET LALLI, GRAVESEND

## Why are some leaves red all year round?

**A** THE RED COLOUR of autumn leaves is caused by the pigment anthocyanin that some trees produce to protect their leaves from the cold. This allows them to stay on the tree for a little longer, so that more of the valuable nutrients can be extracted before the leaf falls off. Some plants produce anthocyanin in other seasons to attract birds or discourage insects. The pigment is also an antioxidant, which helps to protect the tree from bright sunlight and to heal leaf damage more quickly. Many trees have also been specifically cultivated to encourage the red colour, for ornamental reasons. **LV**

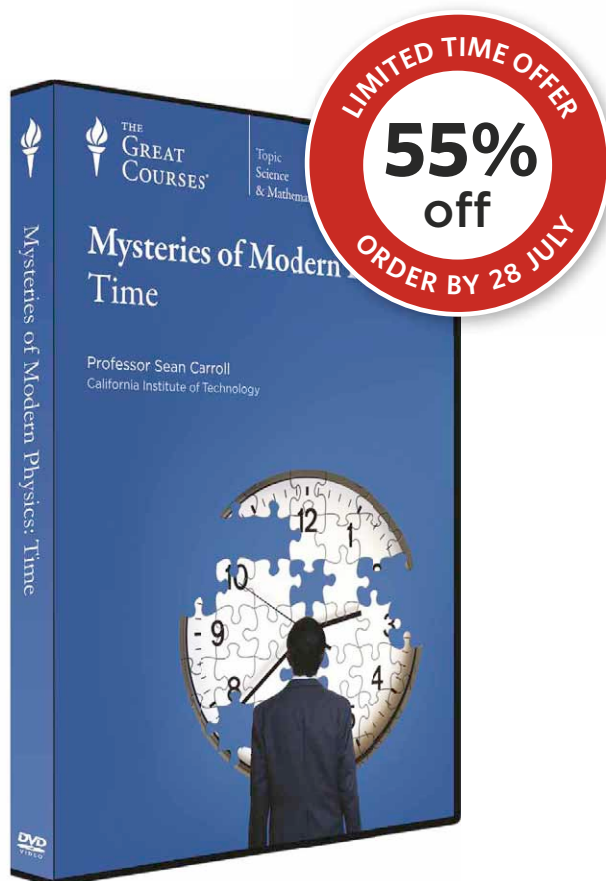
Autumn colours aren't just for our viewing pleasure you know

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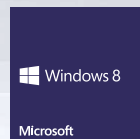
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# HOW TO BUY HAPPINESS

Money *can* buy you happiness. You just have to know how to spend it. **Elizabeth Dunn** and **Michael Norton** share the surprising new science of smarter spending

Illustrations: Dale Edwin Murray

## ELIZABETH DUNN

is an associate professor of psychology at the University of British Columbia in Vancouver



## MICHAEL NORTON

is an associate professor of marketing at Harvard Business School



**M**ANY PEOPLE SAY it, but few believe that money can't buy happiness. After all, have you ever met anyone who's turned down a raise? And yet, decades of research show that the relationship between income and happiness is surprisingly weak. A 2010 Princeton University study of almost half a million Americans found that once individuals

were earning \$75,000 (£49,000) per year, additional income had no bearing whatsoever on their day-to-day feelings of happiness. In fact, how much money you make may matter less than what you do with the money you have.

A tide of new research provides insight into how to use money in happier ways, whether you have a little or a lot. So read on to find out how to spend your way to a happy life. ➔





# BUY EXPERIENCES



➔ NICOLE MANTIE, 37, and her husband Dean, a couple we met during the course of our research, dreamed of going on safari in Africa. But they had bought a house with a bathroom in a dire state, so they figured the safari would have to wait. After hearing their friends' stories of a magical five-star safari, though, they decided to go for it, bathroom be damned.

While it's tempting to judge splurging on a safari as less sensible than investing in a better bathroom, a decade of scientific research reveals the surprising wisdom of their decision. Study after study shows that people get more happiness from buying experiences than from buying material things. Why? Experiences are more likely to bring us together with other people, whereas material things are often enjoyed alone (thankfully, in the case of bathrooms). In fact, research carried out by the College of Business at Stony Brook University, New York, found that a solitary experience

made no more difference to a person's happiness than buying a physical item.

Experiences also make for better stories. In one study, researchers from the University of Colorado discovered that pairs of strangers enjoyed talking more when they discussed experiential (versus material) purchases – and ended up liking each other better. Nicole giddily recounts getting kissed by a giraffe while on safari. No matter what your stance on inter-species saliva swapping is, you must admit this experience makes for a more interesting story than fitting a new loo.

## THE EXPERIENCE CV

In fact, some people seek out extreme, memorable – and even unpleasant – activities to add to what researchers call the 'experiential CV'. In Kenya, Nicole and Dean stayed at an unusual hotel called The

Ark, where guests are regularly roused from their beds in the middle of the night. Although rude awakenings don't sound like the makings of a great vacation, Nicole and Dean were thrilled. They wanted to see The Big Five (elephant, rhino, cape buffalo, leopard, and lion) and were happy to leap out of bed if it meant adding a new animal to their 'collection'.

A sign on the hotel wall explained that the buzzer would go off once for an elephant, twice for a rhino, three times for a leopard, and four times for an 'unusual sighting'. At 3am, the buzzer went off four times and Nicole and Dean rushed out to see the unusual sighting. What was waiting for them? Nicole laughs, "A porcupine." And that's another property of experiences that makes them superior to material things – we can often see the positive (or at least funny) side of experiences, even when they don't work out as planned.

Looking back on their trip, Nicole says





she has no regrets. Recent research conducted at Cornell University shows that people are much less likely to regret buying experiences than buying material things. The researchers asked students to think back on their past spending decisions and describe their biggest single regret. When it came to material purchases, most students described something they regretted buying. But when it came to experiential purchases, over 80 per cent described an experience they regretted not buying when they had the chance. Because experiences seem unique and irreplaceable, we feel more remorse when we let them pass us by.

While Nicole is glad she jumped on the chance to go on safari, her bathroom remains unrenovated two years later. Yet she says, “I wouldn’t trade those memories of that trip for anything in the world. Not even a brand new home.”



For a happy life, build up your ‘experience CV’ – a safari will provide you with good memories long after the paint has dried in a new kitchen, for instance





A new speaker system or more free time? Studies show that time will make you happier in the long run than a material object

➔ **ASIDE FROM ENABLING** you to go on great adventures, money can also transform the more mundane moments of daily life, by allowing you to outsource your most dreaded tasks.

One of us (Mike) experiences what he describes as ‘existential terror’ while doing the dishes. Although most people aren’t launched into their own private Sartre play by a sink full of suds, a study by psychologist Daniel Kahneman, which tried to characterise the average day, showed that housework ranks among the least enjoyable of activities (hardly surprising). But new research by Kahneman suggests that our daily moods depend more on what exactly we do with our time – and whom we spend it with – than on the broader circumstances of our lives. So, rather than spending money on fancier cars and bigger houses, we’re better off using our cash to reduce the amount of time we spend on things that drag down our happiness on a typical day.

## TIME IS MONEY

After one of us (Liz) had a baby, she found herself lying awake most nights with the sleepless infant. Having tried every sleep-training strategy on the internet, Liz called in the big guns: a woman named Claudia with a reputation for being able to teach any baby to sleep. Claudia doesn’t come cheap – for about the same price as a night with Claudia, Liz could’ve purchased the fancy new speaker system they’d been eyeing for months. But by teaching the baby how to sleep better, Claudia did something that a speaker system never could: she transformed Liz’s insomnia-ridden nights into hours of blissful sleep.

Many of our purchases – even those as nice as a speaker system – have little bearing on the way we spend our time

**“Focusing on time, rather than money, pushes people towards happier activities”**



on a typical day. But it’s easy to inflate the potential benefits of a tantalising new purchase. Immersive surround sound! Cinema-like experience! This is amplified by comparison shopping, which can make the 10-speaker system seem infinitely better than a six-speaker system – and well worth the extra £200. Researchers at the University of Chicago found that when people try to visualise how these differences will make their lives happier, they over-inflate the sense of well-being those extra four speakers will bring them.

So, when contemplating a new purchase, we suggest applying the Tuesday Test: think about how the purchase will affect the way you spend your time next Tuesday. Research shows that this simple



# BUY NOW, CONSUME LATER

IT'S NOT JUST what you buy – experiences and time-changers – but how you buy that matters too. It's always tempting to whip out the plastic in a shop, or take a new PC home today and pay for it later in monthly instalments. But debt creates a serious drain on happiness. A study of over 2,000 people by researchers at the University of Sheffield found that individuals with unsecured debt were significantly less happy than those who were debt-free.

We prefer to offset payments because paying in smaller amounts feels instinctively better. In fact, neuroeconomists have found that there's an actual 'pain of paying' that we try to avoid. Scientists from Stanford University discovered that shoppers inside an MRI scanner experienced a pattern of brain activity akin to stubbing a toe when they were shown a high price. So even though it may feel worse at the time, paying up-front to avoid debt paves a better pathway to happiness.

While delaying payment isn't such a great idea, delaying consumption

can be a boon for happiness by allowing us to enjoy the pleasure of anticipation. When researchers from Breda University in the Netherlands tracked the happiness of more than 1,000 holiday-goers in the weeks before and after their trip, they found that people actually experienced their biggest mood boost *before* departure. Looking back on a pleasurable experience can make you happy, but looking forward to it is even better.

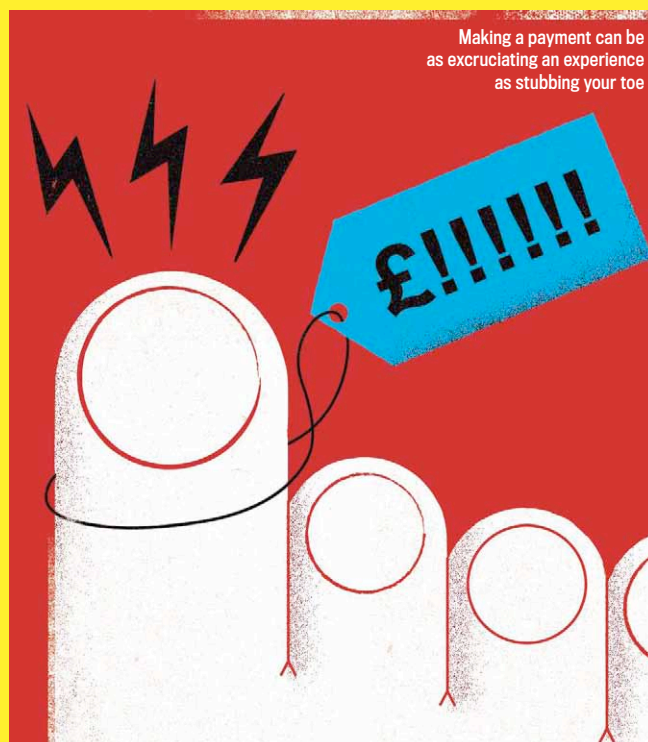
Delaying gratification improves the actual enjoyment of what you're buying too. Research published in the *Journal Of Consumer Research* found that students who had to wait as little as 30 seconds before eating a chocolate bar reported enjoying it more than those who were allowed to scoff it right away. Drooling really does make food taste better. Unfortunately, the students who had been forced to wait told the researcher that they would have preferred to avoid the delay altogether – they didn't *think* they'd enjoyed the chocolate any more than usual. The 'power of now' had dwarfed all else.



thought exercise eliminates our tendency to overestimate how much any one thing will affect our happiness.

Thinking about how purchases will affect your daily life turns decisions about money into decisions about time. This shift comes with a hidden bonus: focusing on time, rather than money, pushes people towards happier activities. In a study conducted at a café in Philadelphia, researchers prompted people to think about time or about money. Individuals with money on their minds ended up working more while they were at the café, whereas those prompted to think about time devoted more of their stay to socialising, one of the happiest activities in most people's days.

Making a payment can be as excruciating an experience as stubbing your toe







Less is more when it comes to treating yourself

## MAKE IT A TREAT

WE CAN SOMETIMES get more happiness not only from delaying consumption, but even reducing consumption. To explore this idea, our student Jordi Quoidbach asked chocolate lovers to come into the lab and eat chocolate on two occasions, one week apart. During the intervening week, he instructed some of them to abstain from eating chocolate. He sent others home with a big bag of chocolate bars and told them to eat as many as they could, while a final group got no special instructions. At the second tasting, the abstinence group got the most pleasure from eating chocolate. This simple study upends the basic assumption that getting more of what we like makes us happier – challenging a central premise of modern economies.

This observation holds true in the real world. A group of motorists with cars ranging in price from \$400 (£258) to \$40,000 (£25,860) were asked by researchers from the University of Michigan to think back to the last time they had driven their car and rate how much they enjoyed the drive. The experiment found that there was no relationship between the value of a car and how much enjoyment the driver got out of it (perhaps they should have quizzed some McLaren owners). But when the same group was asked to recall the last time they had driven their car just for fun, owners of more expensive models were much happier. So, the occasional treat can make the extra money you spend translate into extra happiness.

Knowing that consuming more won't necessarily buy us more happiness suggests it's time to re-think the spending choices we make every day.



**STRANGE ATMs RECENTLY** appeared in cities around Spain. The machines spit out envelopes filled with €100, no card or PIN needed. The only requirement: visitors to the ATM had to click 'yes' when asked whether they were willing to spend the money on others. After coming across one of these mysterious machines planted by Coca-Cola, people went on their way, using the windfall in a variety of ways. Some of their good deeds were captured on video: a young man left a shiny red tricycle at a child's doorstep, another handed theatre tickets to an elderly couple in the park. These small acts of generosity succeeded in embodying Coke's marketing ploy: 'share happiness'.

Coke's free money machines are reminiscent of an experiment we conducted several years ago. Like an ATM sprung to life, our graduate

student Lara Aknin approached people in Vancouver, Canada and offered them \$5 or \$20, which she asked them to spend by the end of the day. She told half to spend the money on others, and half to spend the money on themselves. That evening, we got in touch with each person to ask about their day. Those who spent the money on others felt significantly happier than those who had spent it on themselves.

Of course, it's rare that ATMs or graduate students shower you with free money. But research shows that spending money on others will provide happiness even when you use your own hard-earned cash. In fact, the warm glow of giving emerges even in poor countries where many people struggle to meet their own basic needs. Using data from the Gallup World Poll, we found that individuals who had given money to charity were happier





in both poor and rich countries around the globe. So, the tendency to experience joy from giving might just be a fundamental part of human nature.

## THE GIFT OF GIVING

If this is the case, even very young children might get pleasure from helping others. To test this idea, we teamed up with developmental psychologist Kiley Hamlin. We started by giving toddlers Goldfish crackers. Sure, their faces lit up when they received these fish-shaped treats for themselves, but they were even happier when they got the chance to give these treats away to a friendly puppet.

If you've ever seen a toddler dissolve into fits of tears after being asked to share, you might be wondering whether kids – or adults, for that matter – always experience joy from giving to others. Our research shows that such joy is not inevitable. You

## “Joy from giving might be a part of human nature”

are most likely to feel good about giving when you can see how your generosity has made a difference for someone else. In the case of the toddlers, they got to see the puppet making happy munching noises after getting their Goldfish.

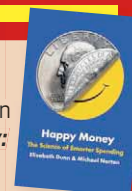
Charities can apply this knowledge by making it easy for donors to see how their contributions are being used. For example, Spread the Net promises to provide one malaria net to protect children in Africa for every \$10 donated. We've found that people get a bigger happiness bang for their buck when they donate to Spread the

Net than when they donate to UNICEF. Even though UNICEF shares the same over-arching mission of helping children in need, giving to this large organisation makes it harder for donors to see the difference their money is making.

Our research also suggests that it's easier to feel good about spending money on others when we spend time with them, too. So, if you buy your nephew a football for his birthday, you're more likely to experience the warm glow of giving if you take the time to kick it around the pitch with him. The next time you reach for your wallet, ask yourself: is this happy money? ■

### Find out more

Elizabeth Dunn and Michael Norton are the authors of **Happy Money: The New Science Of Smarter**





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## ON THE HORIZON

## LG CURVED OLED

**T**HESE DAYS, IF you've got any kind of gadget with a screen on it – whether it's your phone, your laptop or your TV – it's probably rectangular and flat. But that could all be about to change, as this attention-grabbing curved TV from LG demonstrates.

You might have already noticed that the latest ultra-thin smartphones and televisions have been using OLED (Organic Light-Emitting Diode) displays. This screen technology has one key property that makes it attractive to manufacturers. When you pass an electrical current through an OLED it

generates its own light. This means it doesn't require a backlight – the component that bulks up traditional LCDs and LED TVs and makes them difficult to fashion into anything other than a flat box.

LG's new curved OLED, the terribly named 55EA9800 (let's hope they come up with something catchier),







The 55EA9800 made its debut at the CES show in Las Vegas earlier this year



is the first device to go on sale that takes full advantage of this new technology. Sadly, though, it's currently only available in Korea – we will have to wait at least a year to get hold of one in the UK. The 55-inch screen is a slender 4mm thick and has been molded into a gentle curve so that the edges are closer to the viewer's eyes. The whole thing weighs 17kg.

The idea of a curved telly might seem odd at first – you'd imagine it would reduce the viewing angle and possibly warp the image – but it's a formula that's actually proven to be popular with film lovers in the past. The ultimate cinema experience, IMAX, uses a curved display to eliminate visual distortion created when the edges of the screen are much further away from the viewer than centre.

Having laid eyes on this TV ourselves earlier in the year, we can't honestly say that it would make watching *Wonders Of The Universe* any more spectacular. We were mostly just blown away by the sight of a television that wasn't yet another flat, black panel. It's certainly an option that's worth considering if you have your current

set nestled in a corner of your living room – assuming, that is, you've got a spare £8,500 lying around.

While the curved TV probably won't spark a revolution in home cinema, the OLED is likely to shake things up elsewhere. OLEDs don't need to have a glass panel in front of them, unlike other screens, so they can be used in flexible, wearable devices. In fact, Samsung has already shown off the Youm prototype phone, which you can effectively roll up around a lipstick-shaped box that contains the phone's processors and batteries. You can drop the Youm, scratch it or even take a hammer to it and there'll be no damage, since there's no glass to smash – a godsend for the clumsy.

In fact, just about any device with a screen could become flexible, curved and a lot thinner in the next few years if it embraces the OLED. Let's hope, then, that this TV is the first of many.

**DANIEL BENNETT** is the reviews editor of *Focus* magazine

## TECHOMETER

### WHAT'S HOT

#### PASSTHOUGHTS

Hackers are finding passwords increasingly easy to crack, but a group of researchers from the University of California, Berkeley think they have a futureproof solution. Prof John Chuang and his team used a relatively simple £70 brain-reading headset called Neurosky to read people's thoughts while they thought of a word. The unique pattern of brainwave activity created by thinking of a person's favourite song or movie, for instance, was then used in place of a password.

### WHAT'S NOT

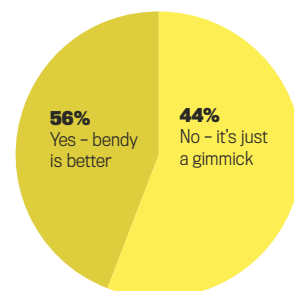
#### BOOKS ON PAPER

Barnes & Noble is selling the basic model of its eReader – the Nook Simple Touch – for just £29 in the UK. While this deal is limited, it shows that an eReader can cost as little as a new hardback, which makes it increasingly hard to justify buying printed books over digital ones. eBooks themselves are typically cheaper than the physical equivalent too, which drove sales up by 134 per cent in the last year. Can trees breathe easy now?



### READER POLL

Would you buy a curved TV?







## EARLY ADOPTER BILL THOMPSON

# FYI: Finding Yourself Indoors

The smartphone-wielding masses have become accustomed to knowing exactly where they are at any moment. One of the last realms that has been left unmapped is the space under our roofs, but that's about to change. A number of companies are working on location-based services that will track your movements indoors and even map the inside of your home.

These new systems aren't actually GPS-based, nor is it likely that a new generation of high-powered satellites will be launched. Instead, they use technologies already built into our gadgets in novel ways.

For example WiFiSlam – recently bought by Apple amid much speculation about its future intentions for the tech – relies on Wi-Fi fingerprinting to deliver its purported 2.5m location accuracy. It measures the strength of your phone's Wi-Fi signal to judge how far you are from the router, and monitors readings from your phone's accelerometers and gyroscopes to get an idea of your walking trajectory. By mating the two sets of data, WiFiSlam pinpoints your location within a building. With enough of this data from hundreds of

phones it can create maps of indoor environments – not just shopping centres and offices but also, in theory, your own home.

There are other methods. The Bluewater shopping centre was among the first to use special Bluetooth nodes to help its shoppers navigate the busy halls. And nearly 30 years ago the Olivetti Research Centre in Cambridge did something



similar with its 'active badges', using infrared sensors in rooms to plot the locations of badge-wearers.

Of course, knowing where you are is only really useful if you have a good map – and sure enough, Google, Microsoft and Nokia are all building their own floor plans and Street View-type imagery of public places. Personally, I can't wait. I used to work in BBC Television Centre in London, a building famous not just for the TV programmes made there

but also for its endless corridors and complex floor plan. Getting lost was a way of life, and most meetings started late because someone was on the wrong floor or – quite often – in the wrong building entirely.

However, our phones' ability to know with ever more precision just where they, and by extension we are, raises many concerns. Apple got into trouble a couple of years ago when it emerged that iPhones were logging user location data for months, and that the data could be easily downloaded and viewed.

Knowing which room of a hotel someone is in, and who else is in there with them, is just the sort of sensitive personal data that we need privacy laws to protect. But all the evidence so far suggests that companies will happily hand it over to the authorities, use it for marketing or simply lose it.

It highlights yet again that our phones are really complex multi-source sensors that just happen to make phone calls and browse the web. And it should cause us all to think carefully about how the data they collect is shared and who controls it.

Bill Thompson contributes to [news.bbc.co.uk](http://news.bbc.co.uk) and the BBC World Service

## COMING SOON

### 3 MONTHS

#### RAZER EDGE



This is *the* tablet for hardcore gamers. It's the size of an iPad, yet packs enough processing power to run blockbuster games like *Battlefield 3*. You can also link it to game pads and a TV for the living room console experience, hook it up to a keyboard for work, or just use it as a media centre. [Razerzone.com](http://Razerzone.com)

**+ New Nexus 7** It's thought Google's next 7-inch tablet could cost under £200. Despite the low price, it's still likely to raise the bar in technology terms. [Play.google.com](http://Play.google.com)

**+ ProDesk3D** This is the world's first 3D desktop printer that prints in full colour. This means you'll be able to create 3D models that use realistic colours, and not just one shade of neon green. [Botobjects.com](http://Botobjects.com)

### 6 MONTHS

#### SONY SMART WATCH



Too lazy to take your phone out of your pocket? Sony hopes so: shown off at CES in January, this Android-powered ticker links to your phone via Bluetooth and shows you new messages, Facebook posts and calendar events. [Sony.com](http://Sony.com)

**+ iPhone 5S** With Apple's stock falling for once, all eyes will be on the launch of the next iPhone in October. A complete redesign of the phone's software is rumoured to be in the works. [Apple.com](http://Apple.com)

**+ PlayStation 4** Gaming goes social with this new Facebook-connected console. Gamers will be able to share their high scores and killer moves at the push of a button. [Playstation.com](http://Playstation.com)

### 9 MONTHS

#### OCULUS RIFT



This pioneering virtual reality headset allows you to step inside games and play like never before. Kits are currently in the hands of games developers, and they hope to get models to the general public early in 2014. [Oculusvr.com](http://Oculusvr.com)

**+ Xi3 Piston** This cube-sized gaming PC will fit in the palm of your hand, yet can offer better graphics than the current generation of consoles. [Xi3.com](http://Xi3.com)

**+ LG flexible phone** Following hot on the heels of Samsung's Youm, LG says it will be releasing a flexible phone of its own before the year's out. [LG.com](http://LG.com)



### TELL US WHAT YOU THINK!

Are you happy for your phone to track your every movement? Give us your opinion by emailing [reply@sciencefocus.com](mailto:reply@sciencefocus.com)





JUST LANDED

# THE FULL FACEBOOK

Mark Zuckerberg wants to take over your smartphone, but should you let him? Sam Kieldsen gets friendly with Facebook Home

## What is it?

Facebook Home is a suite of apps that essentially grabs hold of your smartphone or tablet, replacing its home and lock screens and acting as a launchpad for everything the social network has to offer. Your home screen becomes a slow-moving parade of your Facebook friends' status updates that can be instantly liked with a double-tap or quickly commented upon. Facebook and SMS messages are brought together under the same banner and can be read and replied to without closing the current app you're on.

## Which devices does it work with?

At the time of writing, it's only available on a small selection of Android phones (the HTC One X, HTC One X+, Samsung Galaxy S III, Samsung Galaxy S4 and Samsung Galaxy Note II), but will be rolled out to other Android devices via future updates. The new HTC First phone will come with Home pre-loaded.

## Why isn't it on the iPhone?

The closed nature of Apple's iOS prohibits the level of control that Facebook Home wields over your

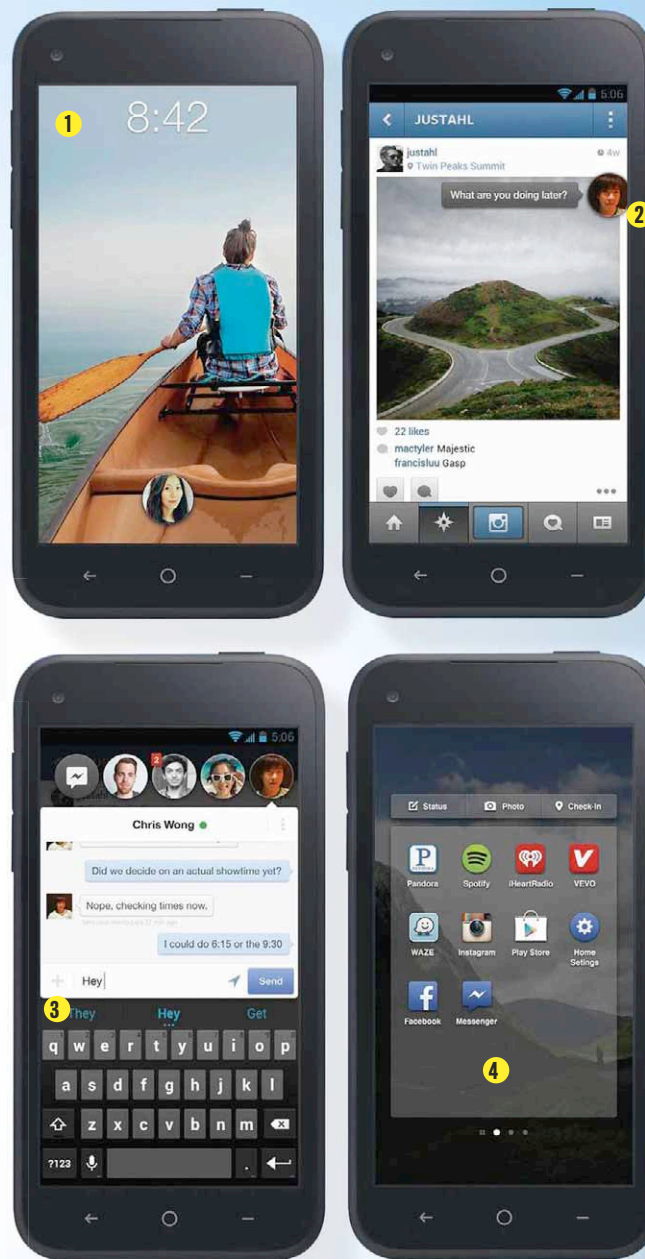
phone, making the open source Android the only real choice for Mark Zuckerberg and co.

## What about my privacy?

Here's the biggest drawback. By inviting Facebook to take over your device it becomes privy to what you do on it. It will know exactly what apps you open and when, but not, Facebook says, what you do with them – so it will know if you open maps on the phone but not what route you're looking for. Of course Facebook could collect this data and customise adverts according to your activity, which would be enough to put us off.

## Should I get it?

Unless you spend most of your smartphone time browsing Facebook, Home isn't really going to improve your life. It disables home screen widgets and corrals all non-Facebook apps and services into a folder hidden behind Facebook, making you do more work to



get to them. The addition of ads in the future is also a cause for concern, as we imagine few will want them anywhere near their home screen. ■

**SAM KIELDSSEN** is a US-based freelance tech journalist

## FOUR FACEBOOK HOME FEATURES

### 1 COVER FEED

A scrolling selection of updates and photos from friends and other things you've 'liked', replacing your home screen.

### 2 CHAT HEADS

This allows you to read and reply to multiple SMS and Facebook messages no matter which app you're using.

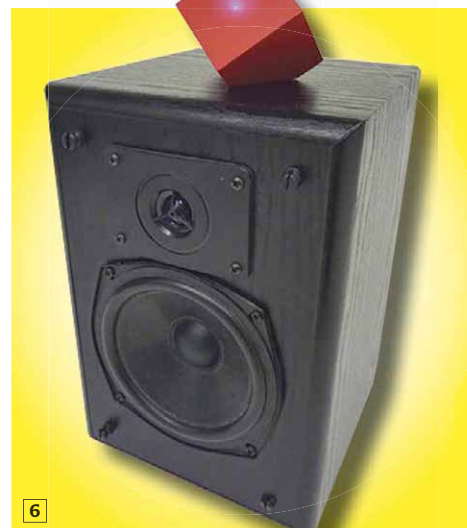
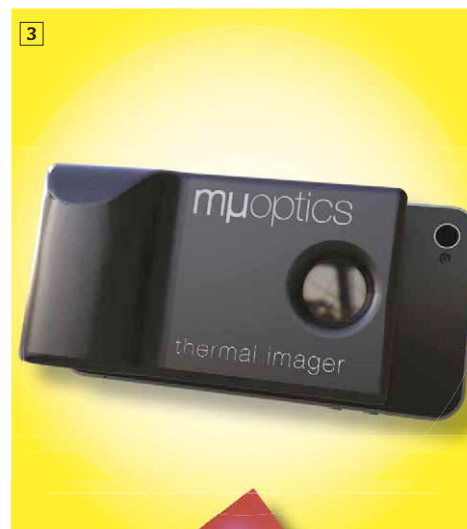
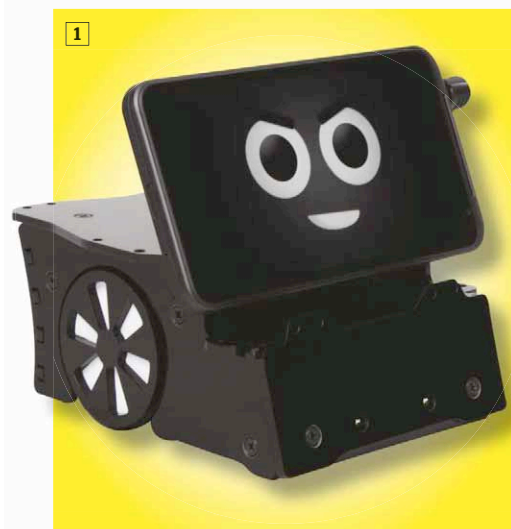
### 3 MESSENGER

Working in tandem with Chat Heads, Messenger now brings your texts and Facebook messages into a single place.

### 4 APP LAUNCHER

Drag your profile pic up from Cover Feed and you'll be shown your phone's non-Facebook apps in a new window.





## APPLIANCES OF SCIENCE

### 1 BABY BOT

If you just use your smartphone to check Facebook, take pics and send the occasional text message then you're wasting its potential. This phone-dock-on-wheels uses your phone's sensors and ultra-fast processors to create a mini-robot, which you can use to learn about robotics. Teach it to become your pet, a remote-controlled camera or even a battle bot.

**Overdrive Robotics Smartbot**

Overdriverobotics.com, £160 (£136)

### 2 ROSE-TINTED SPECS

Normal sunglasses shield your eyes by muting the entire spectrum of light that passes through the lenses. As a result your eyes are safe, but the world looks a little less bright. These smart shades, intended for pilots, filter out harmful UV light and blue light while letting the higher, safe wavelengths through so you can see safely in the Sun without dimming your vision.

**EnChroma sunglasses Cx-UV450**

Enchroma.com, \$449 (£294) plus P&P

### 3 HEATSEEKER

This smartphone add-on transforms your handset into a thermal-imaging camera that otherwise would cost thousands of pounds. It lets your iPhone or Android phone see different temperatures as various hues of red, orange and yellow. This is particularly useful if you want to work out where most of the heat is escaping from your house or if you like to spy on wildlife at night.

**Mu Thermal Imager**  
muoptics.com, \$325 (£213) plus P&P

### 4 A SCANNER CHEAPLY

If you're one of a handful of people lucky enough to have access to a 3D printer, then you've probably exhausted the iPhone case, jewellery and toy designs you can find online and print. In steps the Matterform, the first 'affordable' - they're using that term broadly - 3D scanner. It'll let you take objects from the real world and create 3D digital models of them that you can print, modify, or simply store as a digital copy.

**Matterform 3D scanner**  
matterform.net, \$599 (£394) plus P&P

### 5 BONESHAKE

Instead of using a traditional phone speaker, this rugged Android phone uses a Smart Sonic receiver which, when pressed against your face, sends vibrations through your skull so you can hear your call in even the loudest environments. The handset's thick shell also means that it's protected against impacts, extreme temperatures, solar radiation and water.

**Kyocera Torque**  
kyocera-wireless.com, £249.99

### 6 HIGHER-FI

Give an elderly pair of speakers a new lease of life with this peculiar-looking add-on. The Vamp has old-fashioned positive and negative speaker cable connectors that hook up to senior stereos. This gives them the ability to connect with your smartphone, tablet or PC via Bluetooth or a standard 3.5mm audio jack. It's battery-powered too, so you can hijack speakers wherever you are.

**The Vamp**  
http://paulcocksedgeshop.com, £45



# Love your heart with Cardioace®

"Cardioace® Plus contains plant sterols to help me maintain my normal blood cholesterol levels!"

"I take Cardioace® Original tablets with thiamin to help maintain my heart health."

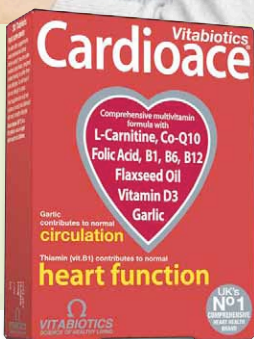
**Cardioace®** has been developed on the basis of extensive worldwide research to help support all round health including nutrients for heart health.

It includes thiamin which contributes to the normal **function of the heart** plus vitamins B6, B12 & folate which contribute to normal homocysteine metabolism.

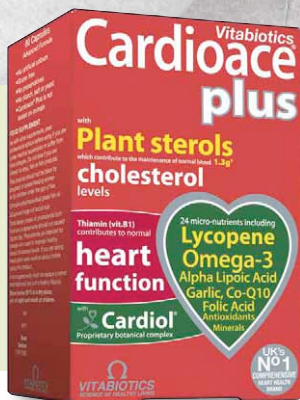
**Cardioace® Plus** contains 1.3g of **Cardiol™** plant sterols which contributes to the maintenance of **normal blood cholesterol levels\***.

Try **Cardioace®** today – from Vitabiotics, experts in nutritional support.

**UK's comprehensive  
No.1 heart health formula**



Cardioace® Original



Cardioace® Plus



## Cardioace® healthy heart tips

The main ways to help maintain a healthy heart and blood pressure include:

- ♥ Eat a balanced diet with 5 or more daily portions of fresh fruit and vegetables to keep your body and heart in top shape.
- ♥ Exercise – try for 30 minutes of moderate exercise 5 times a week.
- ♥ Don't smoke. Smoking can greatly increase the risk of heart problems.
- ♥ Maintain your body weight within the normal range for your height.

Originally developed with


*Prof. A. H. Beckett*  
Prof. A. H. Beckett†  
OBE, PhD, DSc  
(1920-2010)  
Professor Emeritus,  
University of London



  
**VITABIOTICS**  
SCIENCE OF HEALTHY LIVING



  
Britain's leading  
supplements  
for specific life stages

From , Superdrug, Holland & Barrett, GNC, pharmacies, supermarkets, health food stores & [www.cardioace.com](http://www.cardioace.com)

Vitamin supplements may benefit those with nutritionally inadequate diets. † Professor Beckett is not cited in the capacity of a health professional, but as a product inventor and former Chairman of Vitabiotics.  
\*A beneficial effect is obtained with a daily intake of at least 0.8g of plant sterols.





ULTIMATE TEST

# GET SMART

The smartwatch heralds a new age of wearable technology. **Jamie Carter** dons four of the latest

## What is a smartwatch?

A watch is 'smart' if it seeks to go beyond simple time-telling – no, that doesn't include calculator watches – and integrates with another device. To do this it needs a Bluetooth connection to swap data, play music or even let the wearer take a phone call via built-in speakers and a microphone. Some smartwatches have GPS sensors and accelerometers built in, too, but for now they are primarily a smartphone accessory.

## Can I ditch my smartphone for a watch?

Not yet: most are reliant on a Bluetooth umbilical cord that connects them to a smartphone from which they get all their data and their 3G connection. They can tell you what's happening on your phone at a glance, but most will beep wistfully if the Bluetooth link is broken. Even the very latest smartwatches are still dependent on your iPhone or Android device, but expect to see smartwatches with their own data connections becoming standalone devices in their own right soon.

## Will Apple, Microsoft or Google be making a smartwatch?

The rumour mill is awash with talk of all three offering up a wristwatch, but actual details are yet to emerge. If these big brands do weigh in then the whole game could change. Wearable technology that interacts with smartphones is predicted to become a huge business – see Google Glass, for instance – so it seems inevitable that tech-filled watches will be the next must-have gadget.







## COOKOO

www.cookoowatch.com, £110

Works with: iPhone 4S/5, iPad 3/4/Mini, iPod Touch (5th gen)

➔ COOKOO IS A Facebook watch, but there's no screen. A short press of the watch's 'command' button lets out a 'cuckoo' sound on the phone (handy if you've lost it), a medium-length touch reminds you of calendar events through a series of beeps and pushing it longer still checks you into a location on Facebook. To complete either of those last two features, however, requires the phone: all Cookoo does is initiate the process. Oddly, Twitter users are ignored, and so too are text messages. It's all governed by a free Cookoo Time To Connect app, which logs into Facebook and configures how the watch reacts to incoming data

from a Bluetooth-paired smartphone. It beeps and vibrates whenever the paired phone receives an incoming call, email or Facebook message, and again when the battery is running low.

In all other respects, the waterproof Cookoo looks and feels like a regular watch. Powered by a regular watch battery that lasts a month, and with no cables at all, the clock face's hands spin round as normal, completely divorced from its smart features. It's easy to live and travel with and doesn't attract attention as a touchscreen watch might, but its smart features are only partially useful.



## I'M WATCH

www.imsmart.com, £219

Works with: iPhone 4S/5, Android

THIS ITALIAN-MADE WATCH – the only one here with a touchscreen – is all about browsing. i'm Watch tethers to a smartphone using Bluetooth, but configuring features and apps is done online using the i'm Cloud website. Updates are then downloaded the next time the watch attempts a sync, which it does every 15 minutes via smartphone tethering. When it does, Tweets, Facebook updates and emails pop up on its 1.55-inch touchscreen, as well as a caller display when someone calls. The screen, though big for a watch face, is tricky to navigate with touch gestures, a problem that's compounded since it's not particularly sensitive either.

As well as a tiny speaker, i'm Watch has a headphones port and even its own i'Music service. Though it only costs €9.99 (£8.54) for a year's access, i'Music offers only playlists themed around an artist or band. Each song has to be physically downloaded, which is a long process: it's far quicker just to drag and drop mp3s from a computer to the i'm Watch's 4GB drive using a Micro USB cable.

It needs a recharge every day, but in return for what? There's no option for text message alerts, hands-free calling doesn't work and the screen keeps falling asleep. i'm Watch may be smart, but it's not particularly practical.



## GEEK CHIC: BEYOND SMARTWATCHES

**Processors, sensors and wireless connections are working their way into more than just watches. Meet the new wave of wearable gadgets stuffed with embedded tech**

### LARKLIFE

lark.com

With an accelerometer, Bluetooth connectivity and a silent alarm clock built in, this £100 armband is all about fitness. It wakes you up, records your micro-movements during the day, and sends all the information to your phone. Meals can be logged on an app that learns your habits and issues coaching tips.



### MEMETO

memoto.com

This waterproof 'lifelogger' system, which costs £182 and has no buttons, provides you with an instant photographic memory. It takes two geotagged photographs every minute as it builds up a record of everything you see, all of which is instantly sent to a linked smartphone.







## GARMIN F NIX

www.garmin.com, £350

Works with: iPhone 4S/5, Android, Windows, Mac

THIS IS A watch for the outdoors. With a compass, altimeter and barometer inside, the read-out is complex yet very simply laid out, as it records your routes and whereabouts using 32 GPS satellites orbiting the Earth. With hiking, mountaineering, running, sailing, geocaching and fishing modes, it's pretty versatile, too.

It can show speed as well as temperature, while your route can be recorded, uploaded to the free BaseCamp app on a phone or computer via Bluetooth, then shared with the world. There are very basic maps on the watch, but it's on BaseCamp that adventures really come alive, though you do need to purchase

maps separately. Some of the watch's useful GPS tools include the self-explanatory TracBac, and Sight 'N Go – point the watch at something in the distance and it will guide you there. Stargazers will also love Sun & Moon, which gives rise and set times.

Though the battery lasts for about 16 hours and must be recharged via a large USB cradle, it's possible to eke out as much as 50 hours by setting it to find satellites just once per minute. The breadth of the pricey f nix outstrips the other watches here, but it won't appeal to all, and the interface is rudimentary – it does take a bit of getting to know.



## MARTIAN G2G

www.martianwatches.com, £165

Works with: iPhone 4S/5, Android

The G2G NEEDS a good talking to. A tap of a button on this watch and your smartphone's personal assistant – such as Siri or Google Now – is at your service. Despite Siri's accuracy being questionable, it's surprising that the G2G is the only smartwatch that offers voice control. Being told about tomorrow's weather is fine, but more useful are the G2G's voice call abilities. Tell Siri who you want to call and it will dial through, enabling a completely phone-free call, albeit in only basic quality.

The G2G's other features revolve around a tiny 96x16 pixel OLED display, from where it's possible to remotely snap a photo with your smartphone, or

set the watch to beep loudly if it strays too far from your phone. Despite the screen, though, most of the alert functions of the G2G are determined by a simple app. Enter your login details in the free Martian Watch Alerts app and it will push alerts for Facebook messages, Tweets, emails and texts to the G2G, though it doesn't display any text on the watch.

Pairing over Bluetooth is easy, but in our test it frequently lost contact and failed to send alerts, so we'd question its reliability.



**JAMIE CARTER** is a technology journalist for TechRadar

## OAKLEY AIRWAVE

uk.oakley.com

Designed for skiers and snowboarders, the lenses of these £500 goggles overlay live data for speed, altitude, time, battery level – even the 'air time' of your last jump – on an interior heads-up prism display. Built around Android, they link to your smartphone via a wristband.



## iWALLET

iWalletusa.com

This hardbody wallet will only open once it recognises your fingerprint. It links to your phone via Bluetooth and sounds an alarm if the two are more than 5m apart. Future models are said to link to your bank account and become harder to open when funds are low...



## MUSE

muse.totemapp.com

Four sensors in this headband measure the wearer's brainwaves and monitor changes from concentration to relaxation on its Integrated Brain Health app. Manufacturer InteraXon is hoping the user's brain activity could soon control a linked smartphone, tablet or TV.





You'll find part 1 of this article, in the April 2013 issue

# HOW DISEASES SPREAD

## PART 2

BY WILLIAM BYNUM

The 20th Century saw an explosion in our understanding of bacteria, viruses and prions, and the conquering of many diseases

M

OST DOCTORS HAD accepted by 1900 that bacteria was the cause of many common diseases such as cholera, tuberculosis, typhoid fever and scarlet fever. However, there was still much to learn about the patterns of how these and other diseases spread.

The language of warfare entered medicine with the coming of germs. The body seemed to defend itself against the invaders – sometimes successfully, sometimes not. Two basic theories of immunology matured in the late 19th Century. One, the brainchild of the Russian Élie Metchnikoff, argued that the white blood cells were key. These circulate in the blood and are found at sites of inflammation. Pus is mostly dead white cells, and Metchnikoff observed them with his microscope. He injected foreign bodies such as thorns and watched as white blood cells attacked bacteria. He called them 'phagocytes' and hailed them as the body's warriors.

The alternative immunological theory was elaborated by the brilliant

German scientist Paul Ehrlich, who pioneered the development of experimental pharmacology. Ehrlich argued that the body can produce 'antibodies', proteins that fit into foreign bodies ('antigens'), like a key in a lock. His chemical theory explained much about infection, including why a first infection often produces immunity against subsequent exposure to the same disease. Smallpox was always used as the example, since people never got it twice.

Both theories explained part of the problem and both white blood cells and chemical antibodies are part of modern immunology. But the more scientists learned about the immune system, the more complex it was shown to be.

Another puzzle about the spread of 'germs' was elucidated by Robert Koch, who had been instrumental in the original germ theory. He argued that some people could harbour germs without being ill themselves. This 'carrier state' was dramatically realised with the case of Mary Mallon, an Irish cook who infected several

families with typhoid in New York. 'Typhoid Mary' became a cause célèbre as her condition, which was no fault of her own, was diagnosed and she was incarcerated as a danger to the public. She shed typhoid bacilli in faeces and urine, but was not affected by them. Germ theory gave public health officials new powers to isolate and contain people against their wills.

### FOREIGN BODIES

Bacteria were not the only organisms capable of causing disease. Parasitic worms had long been recognised, and in 1898 Ronald Ross capped five years of research in British India by discovering plasmodia in the salivary glands of mosquitoes. Plasmodia are microorganisms that had first been seen in the blood of humans suffering from malaria by Charles Laveran in 1880. Ross's contribution was to show that the parasite was transmitted through the bites of the female *Anopheles* mosquito. This and the discovery that yellow fever was transmitted through the bites





MMR is prepared for injection – a vaccine against measles, mumps, and rubella, it's only possible thanks to centuries of scientific endeavour

## > IN A NUTSHELL

Great advances made in the 20th Century mean we've discovered the workings of the immune system. We can now vaccinate against many diseases, while smallpox has been completely eradicated. However, new viruses have emerged, such as HIV, that are deadlier than ever.



→ of another genus of mosquito, *Aedes*, made medical entomology (the study of insects) – at the time an exciting new discipline. It soon paid off when Charles Nicolle, working in Tunisia, showed that ticks and lice spread typhus. Ross, Laveran and Nicolle each won Nobel Prizes, indicative of the cutting-edge nature of such research.

The infectious agent of yellow fever was a case in point, eventually shown to be caused by a virus. The word was an old one in medicine, and it originally meant simply 'poison'. As laboratory methods improved, and scientists began working with

a cluster of diseases, such as yellow fever, smallpox and rabies, these agents were shown to pass through the filters that trapped bacteria.

Before these discoveries, Martinus Beijerinck (1851-1931) realised in 1898 that the tobacco mosaic virus (he first called it a 'virus') was obliged to multiply in the cells of the plant it infected. This idea, now appreciated as fundamental to our understanding of viruses, was not well received in Beijerinck's time, since it went against conventional scientific wisdom.

Laboratory scientists eventually came to realise that viruses wouldn't simply grow in little colonies on

Petri dishes like bacteria. Chick embryo cells soon became the medium of choice in laboratories, and as scientists grew more adept at manipulating these tiny particles, they uncovered many viruses that caused human disease. Measles, mumps, chickenpox, smallpox, influenza, polio and the common cold were among the diseases with viral causes. Influenza cast a long shadow on this research, since the 'flu pandemic of 1918-19 remains the most devastating epidemic in history, killing more than 25 million people worldwide – greater than the casualties in World War I.

## THE KEY EXPERIMENT

Old-fashioned methods can be just as effective as more modern techniques, as two scientists courageously proved when studying the cause of stomach ulcers



Barry Marshall had the stomach to become his own guinea pig... literally. He won a Nobel Prize for work into the cause of stomach ulcers with Robin Warren

IN 1981, AN Australian pathologist, Robin Warren, noticed that biopsy slides from patients diagnosed with gastric ulcers sometimes contained curved-shaped bacteria and lots of white blood cells (Metchnikoff's 'phagocytes'). He showed the slides to a young clinician doing his gastroenterology rotation, Barry Marshall. They tried to grow the

bacterium, which needed special conditions, but they eventually discovered how to cultivate it.

Making a solution of it, Marshall became his own guinea pig and swallowed the solution. He had symptoms of acute gastric inflammation and when they examined his stomach with a gastroscope, they saw the telltale signs of early ulcer

formation. Convinced that this bacterium was implicated in the common disease of peptic ulcer, they tried to convince the scientific community.

Conventional wisdom had it that the stomach was so acidic that no bacteria could grow there and thus was sterile. But treatments with antibiotics and bismuth solutions produced

excellent results and eventually the world believed.

They demonstrated that simple experiments, of the kind that 19th-Century scientists could have performed, can produce unexpected results. They won the 2005 Nobel Prize for their elegant research. Nature is full of surprises, sometimes uncovered by traditional methods.



Progress was made, however. From 1915 to 1917, Frederick W Twort in London and Félix d'Herelle in Paris discovered what d'Herelle called the 'bacteriophage': viruses that infect bacteria. Bacteriophages were initially seen as more curious than important, but over the next three decades, their analysis helped lay the foundations of molecular biology, modern genetics and the structure of DNA.

## MICROSCOPIC ENEMY

Despite increasing knowledge of viruses during the early decades of the 20th Century, scientists still had no microscope capable of visualising them. This was solved in the early 1930s, when Ernst Ruska and others invented the 'electron microscope'. This used streams of electrons to provide much higher levels of magnification, and virologists could at last see what they were dealing with.

Patterns of infection confirmed that, with many viral diseases, a single episode leaves the person with lasting immunity. This is why diseases such as mumps, chickenpox and German measles are largely childhood afflictions. Similarly, vaccines for viruses are frequently more effective than ones for bacterial diseases. Edward Jenner's cowpox vaccine relied on the cross-immunity that cowpox gave against smallpox, a much more serious disease.

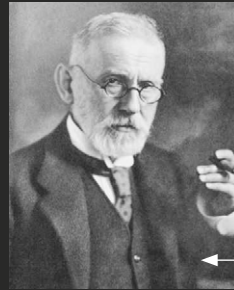
A vaccine for yellow fever was developed in the 1930s, and American scientists worked to find one for polio – probably the most feared disease of young Americans in the middle decades of the 20th Century. After several unsuccessful attempts by various scientists, Jonas Salk announced in 1955 that his vaccine, based on killed polio viruses, was under proper trial. At about the same time, Albert Sabin introduced his own vaccine. This could be delivered orally, on a lump of sugar, so was much favoured by youngsters, and by 1961 had become the vaccine of choice.

There are effective vaccines for many of the other viral scourges of childhood, as well as the bacterial diseases whooping cough and diphtheria. The capacity to understand and manipulate these germs has made childhood a much safer time in the developed world. No medical procedure is completely without



## CAST OF CHARACTERS

The great minds that have unravelled the mechanisms of disease over the last century



**Paul Ehrlich** (1854–1915) was a German medical scientist. A gifted experimentalist, Ehrlich influenced microscopy, tissue staining, embryology, chemotherapy and immunology. His theory of the chemical nature of antigens and antibodies, with a 'lock and key' mechanism of action, was key to understanding infection.



Studies by Dutch botanist and microbiologist **Martinus Beijerinck** (1851–1931) on tobacco mosaic virus (TMV) in the 1890s led to a better understanding of the nature of viruses and their relationship to the cells of the organism they invade.



The American virologist **Albert Sabin** (1906–93) developed a polio vaccine that used an attenuated strain of the virus. It could be given orally (the normal route of transmission of the disease) and from the 1960s became the vaccine of choice in the worldwide campaign against the disease.



**Françoise Barré-Sinoussi** (b. 1947), a French virologist, shared the 2008 Nobel Prize in physiology or medicine for her work on the retroviruses, of which HIV is the most significant. Retroviruses use their RNA in the host cell to make DNA (the reverse of the usual pattern of DNA being used as a template for RNA). She has been active in HIV eradication campaigns worldwide.



The American neurologist and molecular biologist **Stanley Prusiner** (b. 1942) coined the term 'prion', and came up with the theory behind how these misfolded proteins cause grave disease. Prusiner's researches, still not universally accepted, were publicly sanctioned in 1997, when he was awarded the Nobel Prize in physiology or medicine.



## TIMELINE

It took many breakthroughs over the course of a century to unravel the secrets of disease



Marius Beijerinck publishes a study on the tobacco mosaic virus (TMV), arguing that this 'contagious living fluid' (as he called it) needed **another cell in which to reproduce**. TMV was one of the first viruses to be seen using the electron microscope.

1898

1898

Ronald Ross discovers the role of the female *Anopheles* mosquito in the **transmission of malaria**, caused by one or other of several species of plasmodia, a group of single-celled parasites.

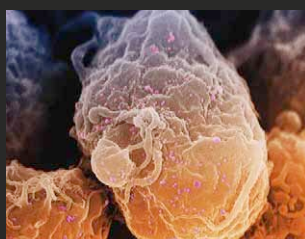
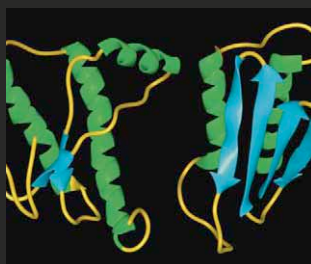


Jonas Salk's **polio vaccine** is tested. The slightly later vaccine, developed by Alfred Sabin and based on live, attenuated virus, dominates the anti-polio campaign, with worldwide eradication still just eluding our grasp.

1954

1982

Stanley Prusiner coins the word '**prion**' (from 'protein' and 'infection'), to describe the class of material causing scrapie in sheep, BSE in cattle and several degenerative disorders of the human nervous system.



Robert Gallo at the US National Institutes of Health and Luc Montagnier and Françoise Barré-Sinoussi at the Pasteur Institute in Paris independently isolate the **virus that causes AIDS**.

1983

➔ risk, however, and popular resistance to compulsory vaccination programmes goes back to the 19th Century, when smallpox was the only vaccine available.

Universal protection is necessary to create the 'herd immunity' to protect mass populations. Smallpox vaccination was part of a concerted World Health Organisation (WHO) campaign against the disease, which led to its global eradication by 1980. The smallpox campaign was run alongside one to eradicate malaria, largely through attempts at mosquito control with DDT. However, the cumulative toxic environmental effects combined with the development of widespread mosquito resistance to the insecticide limited the campaign's effectiveness. It was quietly abandoned after about a decade.

Efforts to make polio follow smallpox into oblivion have been more successful, although pockets remain where health infrastructure is weak.

## CATCHING FLU

These triumphs and failures must be seen beside other diseases. The influenza virus is highly unstable, with new strains demanding vaccines mostly aimed at the current strain. Some of the strains that affect pigs or domestic fowl pose the greatest threat, because they can break the species barrier and threaten human populations. This could cause another global pandemic.

In addition, the modern era has seen the issue of emerging infections. The power of 'germs' to inflict suffering and death is nowhere better illustrated than with the identification, in the USA in the early 1980s, of what was first called GRID (gay-related immune deficiency) and then AIDS (Acquired Immunodeficiency Syndrome). Its early symptoms included fever and sweats, wasting and weakness, a rare kind of tumour (Kaposi's sarcoma) and infections by organisms that are not normally a threat to human beings. The syndrome was soon discovered in Haiti, in intravenous drug users and in haemophiliacs, and its rapid spread caused concern worldwide.

In 1983 the virus, now called Human Immunodeficiency Virus (HIV), was discovered independently by two groups. The virus was almost certainly first acquired in Africa in the early 20th Century, from



## NEED TO KNOW

Understand the history of disease with these key words

### 1 BACTERIOPHAGE

A class of viruses that attack bacteria. Understanding how they act proved instrumental in the development of modern molecular biology and genetics.

### 2 PRION

A misfolded protein that is so tightly bound that it cannot be broken down by ordinary bodily reactions. It acts as an infectious agent by capturing cellular mechanisms and affecting other proteins.

### 3 VACCINE

A substance that stimulates immunity without causing disease. It was named by Louis Pasteur in honour of Edward Jenner's original use of cowpox (vacca is Latin for cow) to protect against smallpox, a much more serious disease.

### 4 VIRUS

A large group of infectious agents that need the cells of a host in order to replicate. Viruses usually contain either DNA or RNA, coated by a protein shell.

chimpanzee meat infected with Simian Immunodeficiency Virus. It smouldered in humans for several decades until changing social conditions ignited it into an epidemic that spread from Africa to Haiti and then to the US.

HIV has become part of the modern disease landscape. As with several infectious diseases, including syphilis, HIV has changed from an acute to a chronic disease, as the germ and the human body have grown used to one another. As the most-studied virus in history, it has led to innovative drug therapies, although it's so changeable that a vaccine has proved elusive.

HIV is not the only 'emerging' disease to have surfaced in the past half century: Ebola virus, West Nile fever, Legionnaire's disease, Lyme disease and SARS (Severe Acute Respiratory Syndrome), are also part of our modern world. In addition, many germs have developed resistance to drugs, and drug-resistant malaria or tuberculosis can act just like a

new disease. On top of this, modern hospitals have become seedbeds for MRSA (Methicillin-resistant *Staphylococcus aureus*). Half a century ago, many people thought that human beings had largely conquered germs. That optimism was sadly premature.

As if emerging infectious diseases were not enough, a whole new kind of infectious agent has been identified as the cause of scrapie in sheep, bovine spongiform encephalopathy (BSE) in cows and Creutzfeldt-Jakob Disease (CJD) and Kuru in human beings. The 'agent', a misfolded protein, was called a prion by Stanley Prusiner in 1982. Although not living in the conventional sense, prions qualify as 'infectious' in their ability to induce other proteins to misfold and thereby become impervious to the normal metabolic processes of proteins. These rogue proteins cause irreversible damage to the nervous system, leading to death within a few months.



A technician at a Ugandan laboratory produces antiretroviral drugs proven to be effective in combating HIV

At the other end of the spectrum from prions, a bacterium was found in 1982 to be associated with peptic ulcer disease. The work overturned decades of debate about the cause of ulcers and offered a much more effective therapy (see 'The Key Experiment' on p90). It won Robin Warren and Barry Marshall a Nobel Prize for work that could have been done a century before.

As the war against disease rages on, it's good to know there are still occasional triumphs. ■

William Bynum is Professor Emeritus of the History of Medicine, UCL, and the author of *A Little History Of Science*

#### Find out more

**BBC** 'Why Can't We Beat Viruses?' is a BBC Science website examining the difficulty in combating viral outbreaks: <http://tinyurl.com/be2ppa4>



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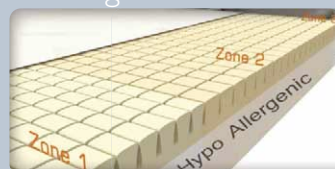
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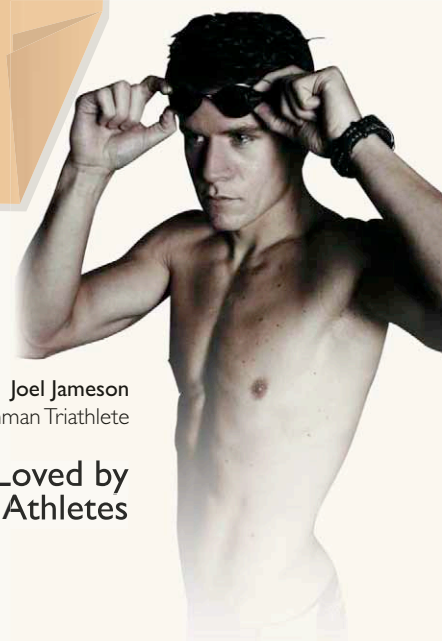
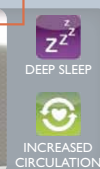
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# TO DO LIST

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## PICK OF THE MONTH



### Science Britannica

Brian Cox presents a three-part celebration of British science (and very small dinosaurs)

➔ CERN PHYSICISTS RECENTLY proposed the existence of a new, hypothetical form of energy. 'Cox energy' is thought to pervade all of space and television, where it is accelerating the expansion of 'wonder' and telescope sales.

*Science Britannica*, a three-part celebration of British science, promises to convert this 'Cox energy' into viewing figures. Having nailed the wonders of life, the Universe and everything, chic geek Prof Brian Cox sets out to explain how science affects all our lives.

In episode one, sitting atop a sunbathed mountain (probably), Cox introduces a group of scientists whose obsessive personalities dragged Britain into the modern world by developing a new way to investigate nature. The 'scientific mind' is explored as Simon Baron-Cohen explains how the focused, autistic-like traits of scientists as a group are a force for good, driving innovative research.

In episode two, looking trendy in front of a waterfall (probably), Cox wonders why science gets such a bad press. Could it be something to do with

long-dead Italian physicist Giovanni Aldini's attempts to resurrect corpses with electricity? Today, science still pushes at boundaries that make some people gag, but as Cox points out, ethically uncomfortable beginnings can generate life-changing technologies.

Finally, astride a grinning space hopper (if only), the floppy-locked physicist ponders the value of blue-sky thinking and accidental discovery against good old-fashioned scientific graft. Should one be able to muse on the bigger picture, or get on with some actual lab work? Nobel Prize winner Paul Nurse believes there is value in both.

Cue music and fade out to a silhouetted Cox dancing in front of spiralling DNA (probably). But then we wouldn't have it any other way, would we?

**HELEN PILCHER**



*Science Britannica* will be shown on BBC Two in June - see [radiotimes.com](http://radiotimes.com) for further details

## DON'T MISS!



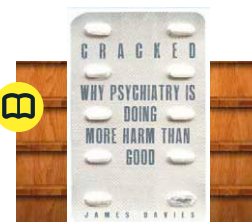
### Illusion

A new exhibition reveals the science that magicians from Dynamo to David Copperfield rely on. p96



### Science Club

Dara O Briain's popular science series returns to our screens this month - here's a sneak preview. p98



### Cracked

A controversial new book argues that psychiatry is a profession that has lost its way - and is doing us more harm than good. p102





# VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

25 MAY - 3 NOVEMBER

## Age Of The Dinosaur

Life Science Centre, Newcastle, for entry fees see [www.life.org.uk](http://www.life.org.uk)



T-REX HAS GOT a bad rep, but its scary cousin, *Tarbosaurus*, wasn't one to be messed with either. At this exhibition, step back more than 65 million years into a Jurassic forest and Cretaceous desert, inhabited by animatronic dinosaurs like the aforementioned killer reptiles. See real dino bones and fossils, then get a taste of marine life from these periods as virtual animals, fish and ammonites swim by.

6, 8, 13, 15 JUNE

## From Fluffy Embroidery To Found Materials

Wellcome Collection, London, check website for times and prices, [www.wellcomecollection.org](http://www.wellcomecollection.org)



USING LIVE BACTERIA, robotics, interactive media, and textiles, Anna Dumitriu's artwork is literally off the wall, blurring the boundaries between art and science. Her installations address fields like healthcare and microbiology, as well as ethical issues raised by emerging technologies. At these hands-on workshops, Anna explains how to create textile-based pieces using recycled and found materials.

15-23 JUNE

## Big Green Week

Various venues in Bristol, for ticket prices see [www.biggreenweek.com](http://www.biggreenweek.com)



'GREENWASH' HAS MADE it into the Oxford English Dictionary. It encompasses all that well-meant stuff that actually hinders reducing our environmental impact, like misleading stats. This eco-festival sorts green fact from fiction. Talks include: radical thinker George Monbiot on positive environmentalism, 'Garbage Warrior' eco-architect Michael Reynolds on sustainable housing and Prof Alice Roberts discussing her latest series *Survivors Of The Ice Age*.

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)

EDITOR'S CHOICE



An expert on sleight of hand, Richard Wiseman reveals magicians' secrets

11 JULY - 29 SEPTEMBER

## Illusion

Science Gallery, Dublin, free, <http://sciencegallery.com>

➔ PAUL DANIELS HAS been given the elbow by a new hip, young crowd of magicians, like street-illusionist Dynamo who wows with mind-bamboozling card tricks and vanishing coin acts. Wonder how he does it? Discover the neuroscience and physics of illusion in this exhibition, curated by Prof Richard Wiseman, author of *Paranormality*.

Find out how what we perceive is often radically different from the reality of what our eyes observe. The exhibition features everything

from classic illusions to virtual reality and magic tricks to street performances, as well as workshops where visitors can create their own illusions.

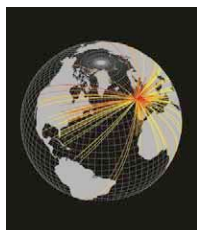
And in case you can't make it to the Science Gallery, we'll let you in on the secret behind Dynamo's vanishing coin act. Spoiler alert! He's exploiting a phenomenon called 'retention vanish' - when your visual neurones continue to fire, so your brain's perception of motion makes you see the coin in the hand for a fraction after it is no longer there. Magic!



**27 JUNE**

## Mapping the Movement Of Humans And Their Diseases

University of Southampton, 7-8pm, for tickets call 01962 886380, [jp.leonard@btinternet.com](mailto:jp.leonard@btinternet.com)



*CONTAGION* GAVE US a taste of the chaos that would ensue if a deadly pandemic ever swept the globe. The film hyped reality, but there was truth behind how a virus could spread from animals to humans – the 2009 swine flu outbreak was a case in point. At this talk, Dr Andy Tatem reveals how scientists track diseases using tools like mobile phones and satellite imagery.

**27 JUNE**

## The Scent Of Space

Royal Institution, London, 7-8.30pm, £10 / £7 / £5, members free, [www.rigb.org](http://www.rigb.org)



WHAT DOES SPACE smell like? To get a whiff, don't try taking off your spacesuit helmet – there's no air in space. Aside from hypoxia, you'd get lethal sunburn and it'd be a tad chilly (around -150°C). Instead, find out from the Royal Observatory's Public Astronomer Marek Kukula (pictured), as he takes your nostrils on an interactive tour of cosmic smells from Venus's acid clouds to the oily seas of Saturn's moon Titan.

**1-7 JULY**

## Summer Science Exhibition

Carlton House, London, free, <http://sse.royalsociety.org/2013>



IS THERE NO end to the talents of 3D printers? They're now printing stem cells, which could create better human tissue models for testing drugs, and even build replacement organs. This is just one of the intriguing exhibits at this year's festival. Plus, there are a whole host of talks from experts and TV presenters such as evolutionary biologist Simon Watt and Greg Foot (pictured), aka the 'Science Daredevil'.

**4 JULY**

## The Life And Death Of The Great Auk

Natural History Museum, London, 2:30pm, free, [www.nhm.ac.uk](http://www.nhm.ac.uk)



MOST FLIGHTLESS BIRDS haven't fared too well throughout history. After all, a bird that's unable to take off isn't one of Nature's best ideas. The Great Auk (pictured) was Europe's version of the Dodo, going extinct a few hundred years later in the mid-19th Century. This talk reveals the lifestyle of this 'penguin from the north', and how it met its untimely demise.

## SPEAKER OF THE MONTH

**5 JUNE**


## Mark Miodownik

Royal Institution, London, 7-8.30pm, £10 / £7 / £5, members free, [www.rigb.org](http://www.rigb.org)

### ➔ Who is he?

Watch out Brian-pop-star-turned-prof-pin-up-Cox, there's a challenger for your crown. Prof Mark Miodownik presents programmes like *Size Matters*, *How It Works* and *The Genius Of Invention*. He's a materials scientist and professor at UCL and in 2010, delivered the Royal Institution's Christmas Lectures. He co-founded the Materials Library, which acts as a lab, studio, workshop and play pen for the material minded, and is part of the Institute of Making – a cross-disciplinary research club for producers of everything from molecules to spacecraft.

### What's Mark talking about?

His lecture 'Stuff Matters' explores why materials behave the way they do. Discover why glass is transparent, how concrete pours then sets, and why paperclips bend.

**UNTIL 14 JUNE**

## Innovation Everest

Royal Geographical Society, London, free, [www.rgs.org](http://www.rgs.org)


**LAST CHANCE TO SEE**

Tenzing Norgay makes it to the summit of Mount Everest in 1953



**Q1 FACT OF the month** – Mount Everest was named after Sir George Everest (actually pronounced Eee-verest). Anyway, the debate still rumbles on as to who got to the summit first. In 1924, Mallory and Irvine were last spotted only about 250m from the top. Did they reach the summit before they died? Currently, Sir Edmund Hillary and Nepalese sherpa Tenzing Norgay are credited with being the first. Sixty years on from this incredible feat, this exhibition looks at the innovative technologies used in their expedition.





# WATCH

TV, DVD, BLU-RAY & ONLINE

WITH TIMANDRA HARKNESS

JUNE TBC

## The Burrowers

BBC Four, late June TBC



NEVER MIND *SPRINGWATCH*, this should be titled *Tunnelwatch* – or perhaps *Ground Designs*. Wildlife presenter Chris Packham worries that voles, moles and other mammals that live underground need a little help with a housing crisis of their own. So he sets up artificial burrows. We hope he's installed cameras so we can enjoy the look on their little furry faces when they see what he's done with a few sheets of MDF.

3 JUNE

## Card Shark

National Geographic, 3 June, 9pm



CARD TRICKS DEPEND on lots of science, including mathematics and psychology, as well as manual dexterity. The improbably named British magician Drummond Money-Coutts travels from London to Paris and Bangkok, showing off his skills with street tricks and stunts. Magic tricks are just part of his repertoire, as he demonstrates how to play card games competitively with the subtle art of cheating. Can he become leader of the pack, or will an angry punter deck him?

3 JUNE

## Brain Games

National Geographic, starts 3 June, 8pm



THIS SERIES ABOUT your mind and brain may not be exactly what you'd expect from a science documentary, because it's presented by 'the Timothy Leary of the viral video age,' Jason Silva. But we're also promised experts in neuroscience, cognition and psychology to examine tricky topics like how we perceive time, the uses of fear and why we lie. Along the way, you might even pick up some tips about boosting your own brain's performance (not the way Timothy Leary did, we hope).

TIMANDRA HARKNESS is a stand-up comedian and a presenter on BBC Worldwide's YouTube channel Head Squeeze

Take an in-depth and amusing look at the frontiers of science with host Dara O Briain

EDITOR'S CHOICE



JULY TBC

## Dara O Briain's Science Club

BBC Two, July TBC

THE IRISH COMEDIAN'S popular science show makes a disastrous return. World-ending scenarios kick things off, or more specifically, how to avoid them: predicting earthquakes, fighting dengue fever and overcoming viruses, plus how we can overcome shortages of vital minerals by mining asteroids.

There'll also be adventures in time, with Dara exploring the cosmic microwave background, developments in regenerative medicine and the psychology of time. If that wasn't enough there's also a look at big data, nanotechnology, and hidden worlds (think microbiomes and multiverses).

Dara and guests will be tackling subjects as diverse as swarm intelligence, the Human Connectome Project and new forensic techniques – currently on trial in Oakland, California – that are being used to identify the location of hidden gunmen.

One programme looks forward into the future, asking what life might be like in the year 2025 and delving into the frightening potential of machines that can control our minds, while another will explore the mystery of dark energy, asking 'What is it that actually holds the Universe together?'. Spoiler alert: it's got nothing to do with sticky back plastic...

10 JUNE

## Ape Man

National Geographic, starts 10 June, 9pm



WE'RE OFTEN TOLD how close we are to the apes, but actor Peter Elliott is closer than most of us. Not genetically, but professionally – he's the film industry's favourite primate. In this series, he puts the human race under an anthropological microscope with an entertaining twist. What can we learn from apes when studying our own habits, power struggles and dating behaviour? Hidden-camera filming, experiments and stunts provide lots of material for expert analysis.

25 JUNE

## I Cloned My Pet

Animal Planet, starts 25 June, 8pm



HOW MUCH IS that doggy in the test tube? Losing your pet is sad, but inevitable, since we live so much longer than they do. Until now. This series follows animal lovers who are prepared to spend hundreds of thousands of dollars to bring back their best friend – or rather, a genetic copy. But will a puppy that shares all its genes with the departed pooch be worth the time, money and emotional investment?

10 JUNE

## Mythbusters

Discovery, starts 10 June, 9pm



Boys and their toys: Jamie Hyneman (left) with fellow science maverick Adam Savage

➔ IT'S THE RETURN of the unbeatable 'stunts, science and special effects' formula, with Adam Savage and Jamie Hyneman putting urban myths and movie plots to practical tests. This time they'll ask *Titanic* director James Cameron why Rose couldn't just share her life raft with Jack, instead of watching him drown.

Also – could putting a corner in your trench save your life in the First World War? And, perhaps less obvious, Adam and Jamie try riding a motorcycle across a lake.

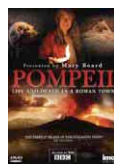
## DVD & BLU-RAY



### The Shard

Demand Media, £14.99

OVER 300M (1,000FT) tall, London's Shard towers over its surroundings, but getting it built was far from straightforward. This documentary follows architect Renzo Piano, who needed over 100,000 tonnes of concrete, 11,468 glass panels and the UK's tallest crane to create the new landmark.



### Pompeii: Life And Death In A Roman Town

IMC Vision, £8.50

FIRST SEEN ON BBC Two, this hour-long documentary presented by Mary Beard looks at what cutting-edge forensic techniques, applied to the skeletons of 54 Pompeii residents that escaped the downpour of ash, can tell us.



### James May's Man Lab Series 3

Spirit Entertainment, £14

JAMES MAY CONTINUES his experiments exploring traditional skills that are in danger of being lost. In this third series, he builds a water clock, travels to a Welsh coal mine to make soap, visits Belgium's Institute of Natural Science, invents a device to warn you if your tea is getting cold and constructs his own model railway mail delivery system.

26 JUNE

## World's Strangest

Quest, starts 26 June, 9pm



JASON BRADBURY TRAVELS the world, seeking out the oddest things human beings have ever found, invented or accidentally created. Then his task is to tease out the underlying science behind the explosions, inventions and weird sleeping habits he's discovered. We look forward to finding out what explains the self-upending ship, the man who flies using the power of water... and the enduring fascination of the weird.

30 JUNE

## Siberian Tiger

BBC Two, 30 June, time tbc



EVER WONDERED WHAT Liz Bonnin does in-between *Stargazing Live* and *Bang Goes The Theory*? Turns out she goes to Siberia in search of the beautiful, deadly and increasingly rare Siberian Tiger. Liz travelled to the Taiga forests in the farthest corner of Russia, learning about the challenges faced by both tigers and people, and how they are attempting to protect the remaining population. The tiger population, that is.





# LISTEN

## BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

WEEKDAYS JUNE

## Tweet Of The Day

BBC Radio 4, weekdays, 5.58am

THE SERIES THAT gives birds their spot on the airwaves continues. In June, Miranda Krestovnikoff introduces seabirds including the puffin and kittiwake, several warblers and a flock of other birds. Each gets a solo spot – a great chance to identify that distinctive call from seaside walks or spooky nights. Find out why the barn owl's head is that shape, and which bird sees the most daylight.



Barn owl head shapes and birdsong – what more could you want at 5.58am? A coffee?

3 JUNE

## Looking For Luddites

BBC Radio 4, 3 June, TBC

CONTRARY TO POPULAR belief, the original Luddites weren't afraid of new technology – they just didn't like the effect the new machines were having on their jobs and wages. In this documentary, technology guru and *Focus* columnist Bill Thompson visits the sites of the original protests, trials and executions, talks to modern trades unionists, science minister David Willetts and anti-technology campaigners, and asks: what would Luddites think of today's factories?

12 JUNE

## Frontiers

BBC World Service, starts 12 June, various times

THE RETURN OF the series that brings you up-to-date with science and technology. Likely topics include messing with microbial communication networks to beat their cunning, antibiotic-resisting ways, growing brain cells in the lab, and building the Crossrail extension under London. More controversially, find out why some scientists think life is essential to the geologically active planet, and whether the hormone oxytocin can help those with social difficulties.

24 JUNE

## The Infinite Monkey Cage

BBC Radio 4, starts 24 June

ROBIN INCE, BRIAN Cox and co are back with their irreverent take on science, inviting guests like Al Murray, Sir Martin Rees and Dave Gorman to address such important question as 'Do parallel universes exist?' and 'Does size matter?' If you can't wait, the Space Exploration podcast is worth a listen to hear Patrick Stewart (Captain Jean-Luc Picard of *Star Trek*) discussing interstellar travel with Brian Cox.



Cox and Ince tackle science's oddities



# TOUCH

## SMARTPHONE & TABLET APPS

WITH CHRISTOPHER PHIN



## Cozmic Zoom

Android 2.1 or later  
Tokata, £1.25

THIS APP TAKES you on a journey from the impossibly tiny to the unimaginably vast, pointing out interesting things along the way. It's basically a way of exploring the Universe, all the way from a proton, via *Homo Sapiens*, to the observable Universe itself, and it's easy to use. As you scroll up or down, the view zooms in or out, and as you go, an optional text box explains what you're looking at. It's by no means exhaustive, but you can tap on terms to do some more exploring on Wikipedia and more.



## From Earth To Space

iPhone, iPod touch, iPad  
Chocolapps, £1.99

IF COZMIC ZOOM (see above) sounds like a fun app but you don't have an Android phone, try From Earth To Space. Like Cozmic Zoom there's a cut-down free version and you're exploring stuff in the Universe – the Mariana Trench, weather balloons, the aurorae and so on – by scrolling up and down. This is definitely aimed at children more than adults, though, and the information is much lighter. Plus, while it goes from the core of the Earth to Ursa Major, it doesn't get into the building blocks of matter. Still, it's charming and fun.



## Sound Uncovered

iPad  
Exploratorium, Free

IF YOU ARE the proud owner of an iPad you should download this app today. You can think of it as an interactive museum exhibit for exploring sound on your tablet. Experience the McGurk effect – where you hear something different when someone says something, depending on whether your eyes are open or closed. Plus you can test how old your ears are, and more. While there's not a huge amount here, what there is is delightful and engrossing.

CHRISTOPHER PHIN is the editor of *MacFormat* magazine



# PLAY

CONSOLE & COMPUTER GAMES  
WITH NEON KELLY



## Company Of Heroes 2

PC; Sega; £39.99

IT'S TAKEN SEVEN years for the lauded *Company Of Heroes* to gain a true sequel, but not even the closure of THQ, the game's original publisher, could stop its eventual arrival. Like its predecessor this is a meticulously detailed slice of World War II strategy, this time focusing on the Eastern Front. Aside from the traditional threats of bullets and shrapnel, your unfortunate troops will freeze to death if you don't look after them. On the plus side, ice looks great when it cracks under the weight of a tank.



## The Silent Age

iOS; House On Fire; free

THIS OLD-SCHOOL point-and-click adventure follows Joe, a humble cleaner whose prosaic existence is interrupted by an ominous visitor – a dying time-traveller who warns of a looming disaster. The ensuing narrative finds Joe hopping back and forth between 1972 and 2012 – a sinister future in which the human race has popped its collective clogs. The story is supported by a witty script and a neatly minimalist art style. This first episode is free, but the developer is currently seeking donations to fund the follow-up.



## Far Cry 3: Blood Dragon

PC, PS3, Xbox 360; Ubisoft; price TBC

DESPITE HAVING 'FAR Cry 3' in the title, this standalone download game has nothing to do with 2012's gap-year-murder-'em-up – nothing aside from the underlying framework, that is. When this was revealed a few months ago, people assumed it to be an April Fools' joke, and it's not hard to see why. It's a bizarre tongue-in-cheek homage to '80s action movies, filled with lasers, robot ninjas, and the omnipresent use of fluorescent lighting. There's even a graphic filter that makes the action resemble a chewed-up VHS tape.



EDITOR'S  
CHOICE

"Stand very still and I'm sure I'll be able to hit that apple on your head. Pretty confident..."

## The Last Of Us

PS3; Naughty Dog; £39.99



➔ IT'S EASY TO forget that Naughty Dog was once best known for Crash Bandicoot – the goofy marsupial who became Sony's closest analogue to a Sonic or Mario. These days the Californian studio deals in cinematic adventures, packed with blockbuster bells and whistles. Having mastered *Indiana Jones*-style ripping yarns with the *Uncharted* trilogy, the developer has turned its attention to post-apocalyptic sci-fi.

In the not-too-distant future, the world has a problem with fungus – and unfortunately, it's not the kind that can be sorted out with cream from the local chemist. A new flavour of *Cordyceps* (look it up) has killed off a large chunk of humanity, and in accordance with the laws of pop culture there are

now only three career paths to follow: fascist soldier, deranged bandit, or victimised survivor. Alternatively, if you get a good lungful of fungus, you can become a hideous mutant with no face.

You take the role of Joel, a hard-nosed black marketeer who becomes the reluctant guardian of Ellie, a mysterious 14-year-old girl. Aside from being a dead ringer for Ellen Page, Ellie is of vital importance to the Fireflies, a resistance movement that wants to overthrow the oppressive military government. Together, Joel and Ellie must traverse the overgrown ruins of America, evading the numerous threats of the quarantine zone.

Where *Uncharted* traded in roguish charm and pulpy heroics, *The Last Of Us* is defined by slow-building tension that explodes into unflinching violence. Cormac McCarthy's *The Road* is a clear influence here, and while the laws of game design necessitate a more action-centric approach to storytelling, Naughty Dog has evidently set out to make a deeply harrowing experience. Provided you have the stomach for it – and a PS3 – this is the most important release of the summer.

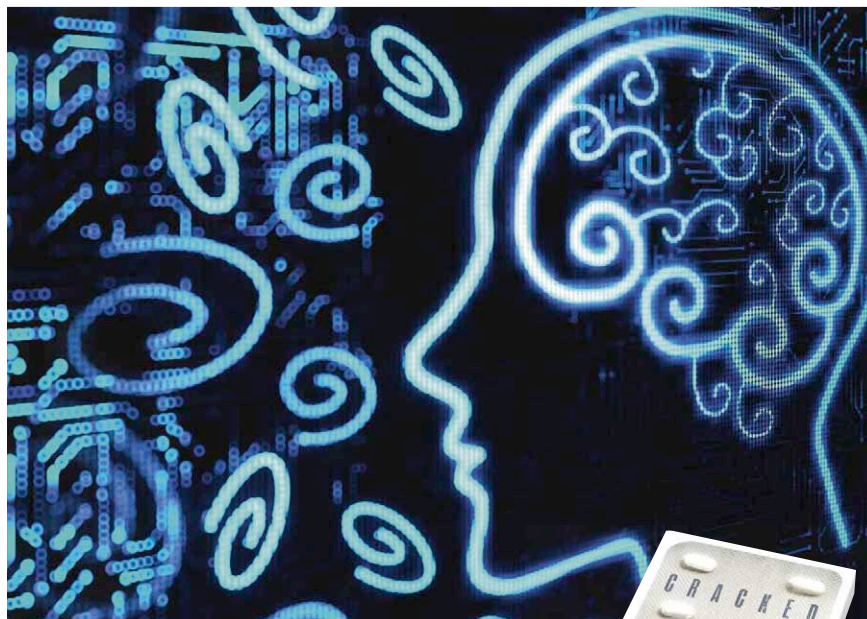




# READ

THE LATEST SCIENCE BOOKS REVIEWED

**H** Hardback **P** Paperback



## Cracked Why Psychiatry Is Doing More Harm Than Good

James Davies

Icon Books **P** £10.99

ONCE UPON A time, long, long ago I studied medicine with the intention of becoming a psychiatrist. I finally decided not to pursue that profession because, at least in part, I wasn't convinced that I would really be able to help people change.

One of the problems with psychiatry is that it is so hard to make a diagnosis and be confident that your diagnosis is correct. Even when you are reasonably sure of the diagnosis, the range of available effective treatments is not great. Yet in an age where depression, anxiety and psychosis are rife, we need hope. *Cracked* doesn't offer much of that scarce commodity.

James Davies lays out his agenda at the start. He is going to 'take apart a profession that in the name of helping others has actually been helping itself'. He sets out to answer three questions. Why is psychiatry growing ever more dominant in our culture when its success rates are so low? Why are we consuming

so many drugs when most of those drugs don't work? And, finally, why does psychiatry keep adding to the list of mental disorders it believes exist?

Over the course of the book he builds a disturbing picture of a profession that is in thrall to pharmaceutical companies busy pedalling drugs, such as antidepressants, which we don't understand and which, he argues, rarely work any better than placebo. It is, in his opinion, a profession that has lost its way.

I'm sure there is some truth in what he describes, but it is not a vision that will encourage idealistic medical students to want to join the ranks of psychiatrists and make changes from within. If you weren't depressed at the beginning, you will be at the end.



**MICHAEL MOSLEY** is a writer, doctor and BBC science presenter

### MEET THE AUTHOR



**James  
Davies**

#### What's your book about?

It's about the side of psychiatry that most people are oblivious to: the side that's led psychiatry to perpetrate harm in the name of doing good. For example, more and more people are being unnecessarily medicated, even though we now know that psychiatric drugs don't work in the way that many of us have been led to believe. Studies show that antidepressants, for instance, work no better than placebo pills around 80 per cent of the time.

#### Why write the book now?

Psychiatry hasn't touched so many people's lives as it's doing today – more people are being diagnosed and medicated than ever before. There were 46.7 million prescriptions of antidepressants dispensed to the English public in 2011 alone, and I think that this is going to increase with the publication of the new edition of the *Diagnostic And Statistical Manual Of Mental Disorders* this year. So the time is right for robust critical scrutiny of the industry.

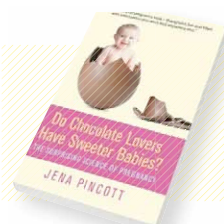
#### Has can we solve the issues with psychiatry today?

There needs to be a greater awareness of psychiatry's limitations, and more transparency regarding its financial ties to the pharmaceutical industry. We also need to equip the next generation of psychiatrists with knowledge about how to approach emotional problems in different ways [other than prescribing drugs]. Finally, we need a better-informed public. My book isn't prescriptive – I'm just trying to offer the reader the information they need in order to make an informed decision about psychiatric treatments.



#### MORE ON THE PODCAST

Listen to the full interview with James Davies at [sciencefocus.com/podcasts](http://sciencefocus.com/podcasts)



## Do Chocolate Lovers Have Sweeter Babies?

**The Surprising Science Of Pregnancy**

Jena Pincott

Souvenir Press **P** £18.99

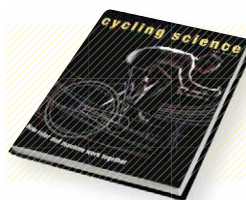
I CRAVED TWO things throughout my pregnancies: information and chocolate. Third time round, it was hard to satisfy the info-craving – I was just re-reading the same old pregnancy books. Fortunately, I could still get my hands on chocolate.

Pincott has written for the 'information-hungry mother-to-be who is seeking a deeper understanding of what's happening to her'. She wrote it while pregnant with her daughter and peppers it with chatty anecdotes about her own experiences. These balance well with the scientific research she explores to answer questions like: do skinny chicks have more daughters? Is there a purpose to painful birth? Even... can men breast-feed? (She concludes that technically they can!)

Written in manageable chunks – 'I write with insomniac nights and waiting rooms in mind' – it's packed with facts like: the baby's brain grows 250,000 new neurones per minute during gestation. As for chocolate, she devotes several pages to how its compounds make your developing foetus happier. In-depth, yet accessible, this a great read for any info-craving mother (or father) –to-be.



EMMA BAYLEY is a contributing editor of *Focus*



## Cycling Science

**How Rider And Machine Work Together**

Max Glaskin

Frances Lincoln **H** £20

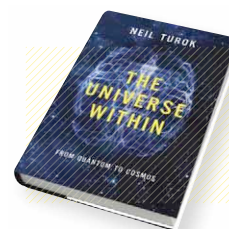
A BEAUTIFUL DAY... time to hop on the saddle, caress those pedals clockwise and cruise to the nearest loch-side pub. Not in *Cycling Science*. Here you place your gluteus maximus on layers of polybutadiene, lean forward applying 240 Newtons to the aluminium bars and generate 100 contractions per millisecond from your fast-twitch muscle leg fibres to propel your steed forward at such a speed that centripetal force keeps you upright.

Each chapter sees technology writer and bike nut Max Glaskin explore an attribute of biking performance. Aerodynamics, frame material, fitness... Glaskin has gathered data from hundreds of scientific journals into palatable nuggets, aided by the use of infographics.

You'll discover that carbon fibre's high measure of stiffness means it's the pro's frame of choice, how slipstreaming your mate's rear wheel can save you 35 per cent energy, and why plasma generators embedded into frames to manipulate airflow are the future. It's a fascinating read, and though more action photos to break up the illustrations would have been appreciated, this is a great book for the two-wheeled aficionado.



JAMES WITTS is the editor of *220 Triathlon* magazine



## From Quantum To Cosmos

**The Universe Within**

Neil Turok

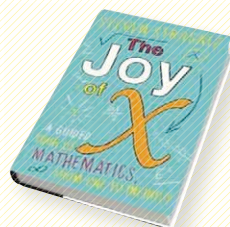
Faber **H** £17.99

EVERYONE LIKES A bargain, so how about this: the keys to the cosmos for the price of a hardback book? That's what cosmologist Professor Neil Turok is offering with this latest addition to the genre of world-renowned theoreticians explaining the deepest mysteries in science. Better still, he's also thrown in an exceptionally clear user's guide – which is just as well, as the keys to the cosmos are made out of maths, not metal. A set of them appears inside the book (find 'em!), which is a real selling-point, as they're normally only to be found in very esoteric research papers, and then without the user manual.

That's the good news. The bad news is that before you get to the keys you'll have to wade through a lot of (to quote the dust-jacket) 'very personal' reflections on everything from apartheid to the works of the Scottish philosopher David Hume. This means Turok doesn't deliver on the science until page 23. But when he does, he serves up possibly the most readable account available of the search for the fundamentals of nature from Newton's laws to Higgs fields and cosmic inflation. A flawed gem.



ROBERT MATTHEWS is a visiting reader in science at Aston University



## The Joy Of X

**A Guided Tour Of Mathematics, From One To Infinity**

Steven Strogatz

Atlantic Books **H** £20

THE PHYSICIST RICHARD Feynman once remarked, "To appreciate nature, it is necessary to understand the language that she speaks in." The language he was referring to was maths, a subject that people often try to avoid. Strogatz aims to tackle this indifference, providing a lively introduction to mathematical ideas that permeate our lives. As well as exploring the curious properties of numbers and shapes, he reveals the importance of calculus and statistics, and even touches on trickier topics like group theory.

It is inevitable that in such a wide-ranging book you'll end up on a well-trodden path,

but Strogatz keeps it interesting by littering the route with entertaining observations. The quirks of curves are explained by looking at the whispering gallery of New York's Grand Central Station, and arithmetic with negative numbers is described as historical alliances between countries. Capturing the playfulness of the subject, the book shows even abstract concepts can be accessible. If maths is the language of nature, *The Joy Of X* is a superb phrase book.



ADAM KUCHARSKI has a PhD in maths and is an award-winning science writer



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## 104 / FOCUS / JULY 2013





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If you didn't get the opportunity to visit the Birmingham NEC, here's some of the tech that adorned the show floor.



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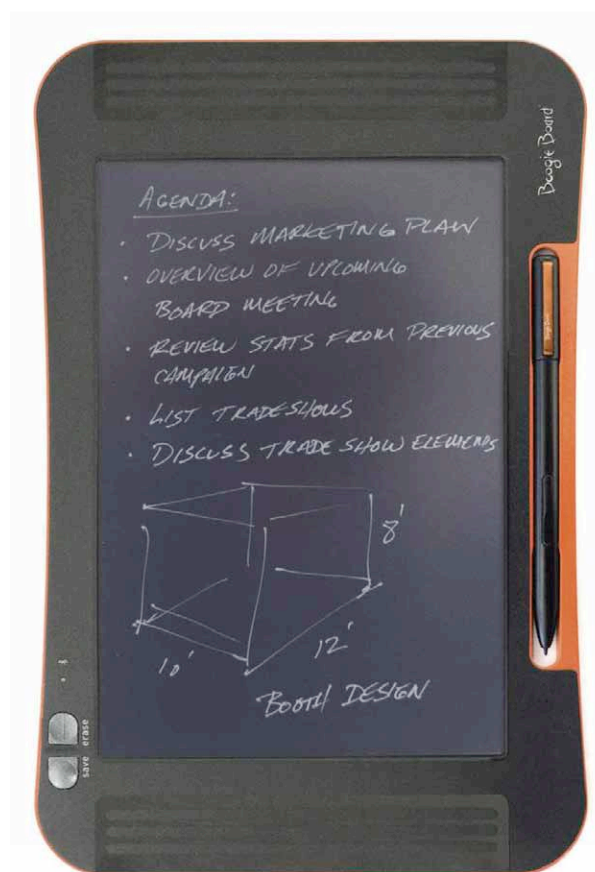
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Published by AstroSpace Publications


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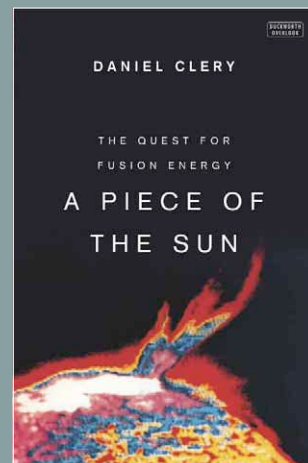
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# MINDGAMES

**BBC FOUR** Pit your wits against these brainteasers by David J Bodycombe, question-setter for BBC Four's *Only Connect*

## PRIZE PUZZLE

Using any two 2-digit whole numbers sharing a common digit, in how many cases can you 'cancel out' the repeated number to leave a whole number result that equals what you started with? On the right,  $64/16 = 4/1 = 4$ .

$$\frac{\cancel{6}4}{1\cancel{6}} = \frac{4}{1}$$

## WIN! TEST YOUR BRAIN ON DVD

The first five correct entries win a copy of *Test Your Brain* on DVD (National Geographic, £12.99).

Post your entry, marked 'Prize Puzzle 256', to: *Focus* magazine, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 27 June 2013. We regret that we cannot accept email entries for this competition. See [sciencefocus.com/winners](http://sciencefocus.com/winners) for a list of previous winners and solutions.



See bottom of p104 for terms and conditions. Congratulations to Bryan Moiser (Hull), Andrew Holmes (Northumberland), S Denny (Surrey), Malcolm Levy (Milton Keynes) and Hannah Walker (Cambridge), who all answered April's Prize Puzzle correctly to each win a copy of *Wonders Of Life* on DVD.

### Q1

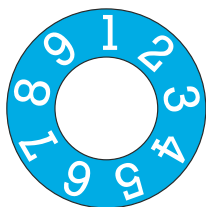
If you delete two letters from the word STANDARD, you'd get the first three terms of which well-known sequence?

### Q2

A standard die is rolled. The tortoise moves 1 to 4 metres on a roll of 1 to 4. The hare moves 5 or 6 metres on a roll of 5 or 6. Who would you back to win a 1km race?

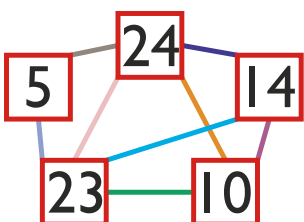
### Q3

Draw three lines to cut the disc into three pieces each totalling the same amount.



### Q4

Inside each box is a whole number. The numbers you can see are the total of the numbers connected to that box, excluding that box itself. Find all the numbers.

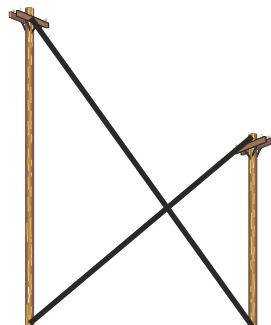


### Q5

48 soccer teams are playing in a double-elimination tournament where your team stays in unless they've lost twice. An odd number of matches was played before a winner was decided - how many?

### Q6

These telegraph poles are 6m and 4m high. How high above ground do the two wires cross?

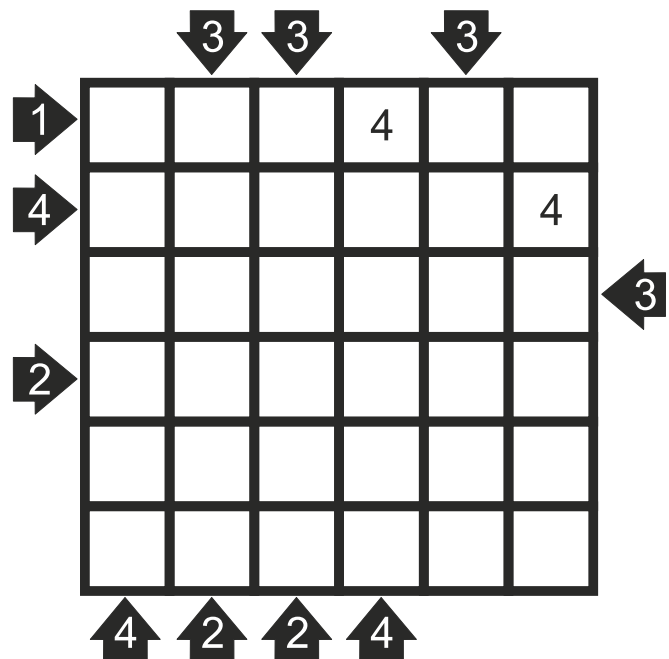


### Q7

You offer to buy a £7 item with a £20 note and yet the shopkeeper asks if you have a £50. Why might this happen?

### Q8

The 6x6 grid represents the 36 blocks of a city plan. Each row and column contains six skyscrapers of different heights (1 to 6 storeys each). Four building heights have already been marked. The arrows show how many of the skyscrapers a viewer, looking from a long distance away, could see in that row or column - with some shorter buildings impossible to see because they are behind taller ones. Complete the grid.



## SOLUTIONS

Q1) 1ST, 2ND, 3RD...  
Q2) The tortoise moves an average of  $(1+2+3+4+5+6)/6 = 3.5$  metres per roll. The hare moves an average of  $(5+6)/2 = 5.5$  metres per roll. So the hare should win.  
Q3) Divide into: 9/12, 4/6, 7/8 - each totalling 15.  
Q4) Clockwise from the top: 2, 5, 9, 3, 7, 1.  
Q5) 95 matches (each match creates one loss, and 94 or 95 losses are needed to determine the winner).  
Q6) See illustration on p104.  
Q7) £13 in coins, or offer £50 and receive back two £20s and £3 of coins.  
Q8) Either solve this using  $y=4x$  and  $y=6x+5$ , or directly via:  $(6 \times 4)/(6+4) = 24/10 = 2.4$ m. Curiously, the answer doesn't depend on the distance between the poles.  
Q9) They have no £5 or £10 notes. You'd either have to receive £13 in coins, or offer £50 and receive back two £20s and £3 of coins.



## QUICK QUIZ

Test your knowledge of gases

**Q1** .....

Which gas makes up most of the Earth's atmosphere?

- a) Oxygen
- b) Nitrogen
- c) Carbon dioxide

**Q2** .....

Which of these elements is a gas at room temperature?

- a) Bromine
- b) Iodine
- c) Chlorine

**Q3** .....

What's the scientific name for laughing gas?

- a) Nitrous oxide
- b) Sulphur dioxide
- c) Carbon monoxide

**Q4** .....

What's the main component of natural gas?

- a) Carbon dioxide
- b) Methane
- c) Nitrogen

**Q5** .....

Complete the sentence: 'At constant pressure, as the temperature of a gas increases, its volume ...'

- a) Increases
- b) Decreases
- c) Stays the same

**Q6** .....

Which of these elements is not a noble gas?

- a) Neon
- b) Helium
- c) Fluorine

**Q7** .....

An ozone molecule consists of how many oxygen atoms?

- a) One
- b) Two
- c) Three

ANSWERS:

Answers: 1b, 2c, 3a, 4b, 5a, 6c, 7c

YOU ARE:

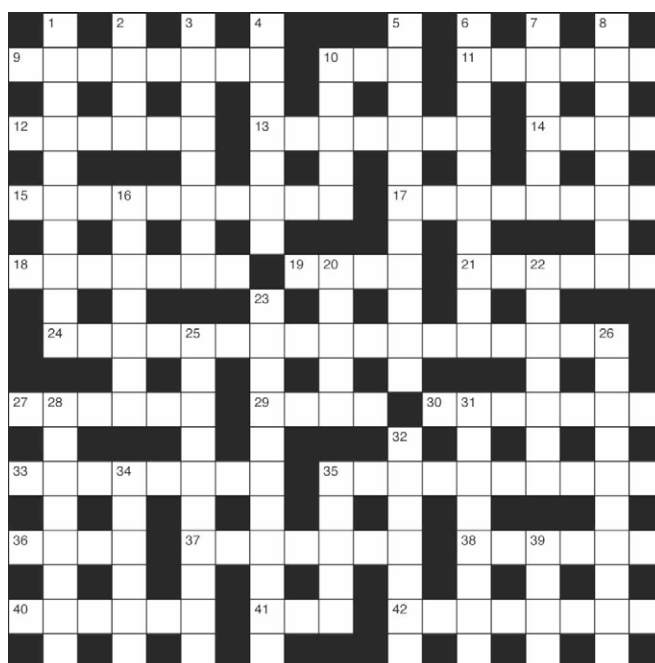
0-3 Out of gas

4-5 Stepping on the gas

6-7 Cooking with gas

## FOCUS CROSSWORD No 152

EVERY MONTH, A NEW CHALLENGE  
SET BY AGENT STARLING



### ACROSS

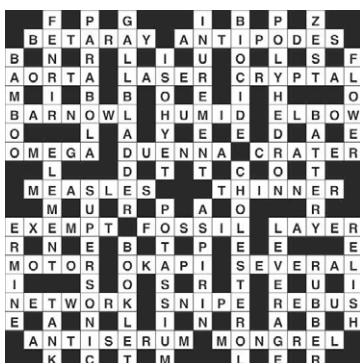
- 9 Dislike a form of therapy (8)
- 10 Self-regulatory organisation has standing room only
- 11 Plant makes variable projectile (6)
- 12 Tiny bit in favour of putting on weight (6)
- 13 Prosperous artist from ancient Syrian city (7)
- 14 Uncovered a painting (4)
- 15 Ochre denim designed like a starfish (10)
- 17 Element used at hill with hesitation (8)
- 18 Scandinavian ship managed to follow course (7)
- 19 Argue endlessly about cattle (4)
- 21 Tenor left with unknown score (6)
- 24 Trendiest clansman displays Kantian philosophy (17)
- 27 One insect let off by another (6)
- 29 Tower of inclination (4)
- 30 Dog said to go mad for cod and hake (7)
- 33 Combining carbon, oxygen and gold, god made a writer (8)
- 35 Gesture with vigour that's renewable (4,6)
- 36 Seafood right inside taxi (4)
- 37 Logical to perform a turn with a trainee (7)
- 38 Treatment for drink problem doesn't start (6)
- 40 At home, enjoy only colour (6)
- 41 He's on the staff (3)
- 42 See rates improve for tiles (8)

### DOWN

- 1 Banned substance on the edge of some land (5,5)
- 2 Material that's loose but shows courage (4)
- 3 Losing EU order, like wood (8)
- 4 Cut favourite fragment (7)
- 5 Tyres openly waste insulation (11)
- 6 A harpy can't cultivate a shrub (10)
- 7 British symbol by Latin engineer (6)
- 8 German takes ancient dirt to be a valuable item (4,4)
- 10 Males affected by site of witch hunt (5)
- 16 Rascal left worker to graft (7)
- 20 Danes out of range (5)
- 22 Typical example of a pie recipe, to my eyes (7)
- 23 Moderate a true form of heat (11)
- 25 Inventor sent the pens to boy (10)
- 26 Mark follows crazy Ottoman ruler to the island (10)
- 28 Old crone worried about one gland (8)
- 31 Stone makes them stay fresh (8)
- 32 Throw out veal and produce an egg (7)
- 34 Rumba spread around Italy, or part of it (6)
- 35 Conversation has left the planet (5)
- 39 Shelter king from vegetable (4)

### SOLUTION TO CROSSWORD No 149

A Wiseman, N Armstrong, L Pratt, Stuart Milner and Andy Bell solved issue 253's puzzle and each receive a copy of *Stephen Hawking's Grand Design* on DVD.



### WIN A COPY OF 30-SECOND ASTRONOMY - THE 50 MOST MINDBLOWING DISCOVERIES... (ICON BOOKS, £12.99)

The first five correct solutions drawn will each win a copy of *30-Second Astronomy* (Icon Books, £12.99). Entries must be received by 5pm on 27 June 2013. See below for more details.



### YOUR DETAILS

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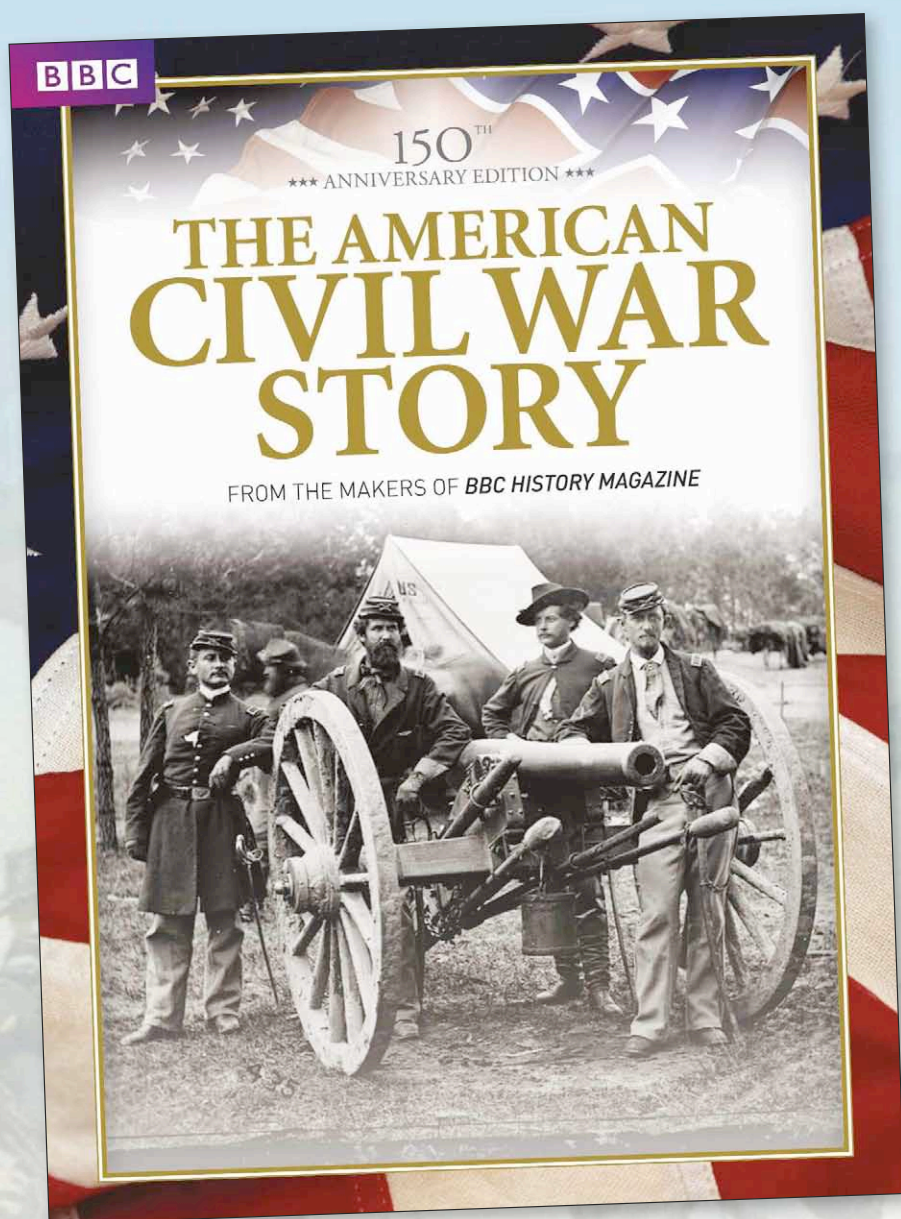
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Post entries to Focus, July 2013 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to [july2013@focuscomps.co.uk](mailto:july2013@focuscomps.co.uk) by 5pm on 27 June 2013. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 104. Immediate Media, publisher of Focus, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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## INTO THE FUTURE

# STEPHEN BAXTER

**H**EADLINE NEWS WAS made in March 2013 when a new map of the Cosmic Background Radiation – a relic of the Big Bang – was released. Compiled from results from the European 'Planck' space telescope, it showed that the Universe, at 13,820 million years old, is 50 million years older than previously thought. That's an adjustment of a mere one-third of 1 per cent, a measure of the precision of the science.

By comparison, the Universe's future is much more uncertain. Life on Earth will probably end in a billion years, as the Sun heats up. But will the Universe itself end? If so, how? And what will become of life and consciousness in the very far future? Our answers to these questions change as cosmology, the study of universal evolution, advances.

The science of the end of everything was born in the 1860s with Rudolf Clausius's theory of entropy. The Second Law of Thermodynamics dictates that usable energy sources (such as stars) must gradually run down. The ultimate destiny of mankind, faced by this 'Heat Death', looked bleak. In the 1930s, as the cosmologists learned that our Universe is expanding in all directions, it looked as if Clausius must be right; the cosmos of the far-future would be a dark, expanding void full of the husks of dead stars.

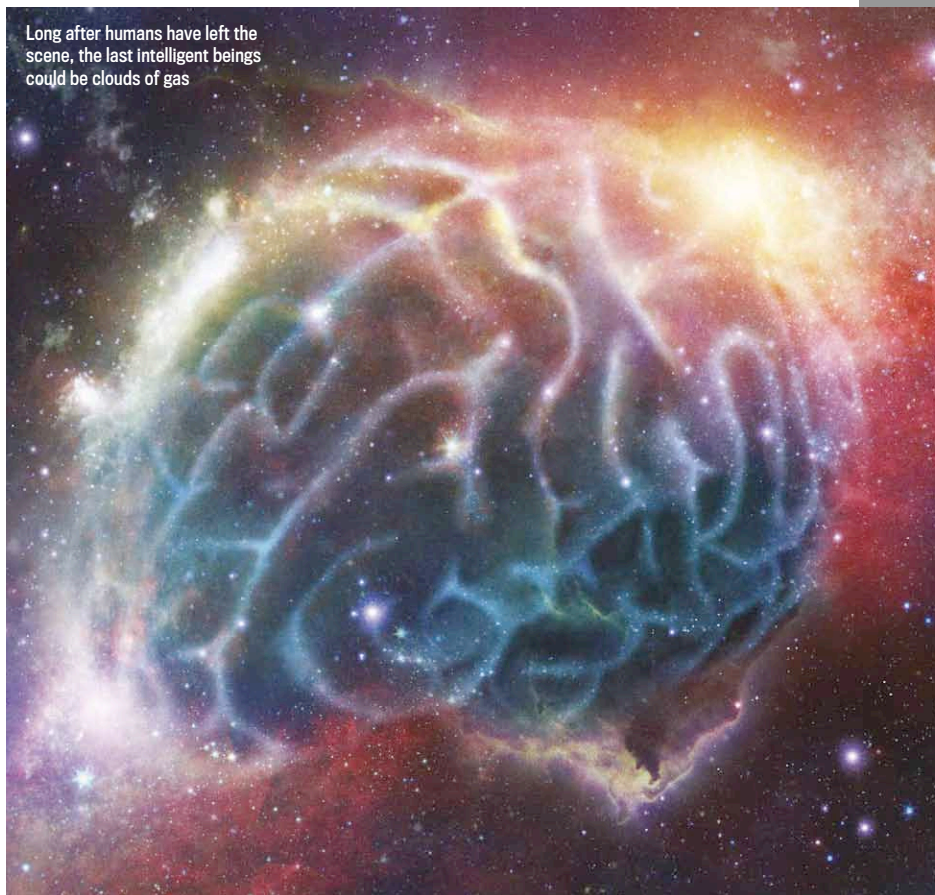
However, in 1979 Princeton physicist Freeman Dyson showed that as the Universe expands, even though the Second Law will hold overall sway, it might be possible in principle for a computer to continue to work for an infinitely long time. The trick is for the computer to work more and more slowly as the energy runs down. And if a computer could survive indefinitely, so, possibly, could consciousness. The Universe would be vastly expanded, with the stars long dead, matter spread cold and thin, and the remaining energy very sparse.

Nothing like a human body could survive. Inhabiting this environment, the last intelligences would be like immense clouds of gas, light-years across. And because of the time it would

take for signals to cross such a diffuse 'brain', it would take longer to complete a single thought than it once took species to rise and fall on Earth. Yet computation, and perhaps consciousness, could persist.

Alternatively, perhaps we live in a closed Universe – that is, the Universe may eventually stop expanding and collapse back to a 'Big Crunch'. In 1994 physicist Frank Tipler, in a kind of inverse of Dyson's work, showed that far-future intelligences could manipulate the final Crunch to provide an energy source that could run an infinite number of computer-program steps. Again, if a computer could survive so perhaps could consciousness, thinking an infinite number of thoughts and so achieving eternal life, even in the finite time left before the Crunch.

Long after humans have left the scene, the last intelligent beings could be clouds of gas



**“Will the Universe itself end? If so, how? And what will become of life in the very far future?”**

These prospects might seem inhuman, but at least they offered the hope of an essentially infinite future. But the news got worse in the 1990s when astronomers discovered, through observations of distant supernovae, that the Universe was expanding faster than earlier theories predicted. It's all to do with dark energy, which is like an antigravity field permeating the Universe. In the end, according to a suggestion by Richard Caldwell of Dartmouth College in 2003, everything will be torn apart by dark energy, starting with superclusters of galaxies, but in the end stars, planets, human bodies, even atoms. Not even Dyson's cloud-minds could survive. This 'Big Rip' would be trillions of years away, but this appeared to be the end of hopes.

However, I wouldn't despair just yet. The latest results from the Planck telescope also contain new estimates of the amounts of mass and energy in the Universe; we certainly don't have it all nailed down.

Given how rapidly cosmology is advancing, I confidently predict that our story of the Universe's future, and our own, has a few surprises to come. ■

**STEPHEN BAXTER** is a science fiction writer whose books include the *Destiny's Child* series and *The Science Of Avatar*

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